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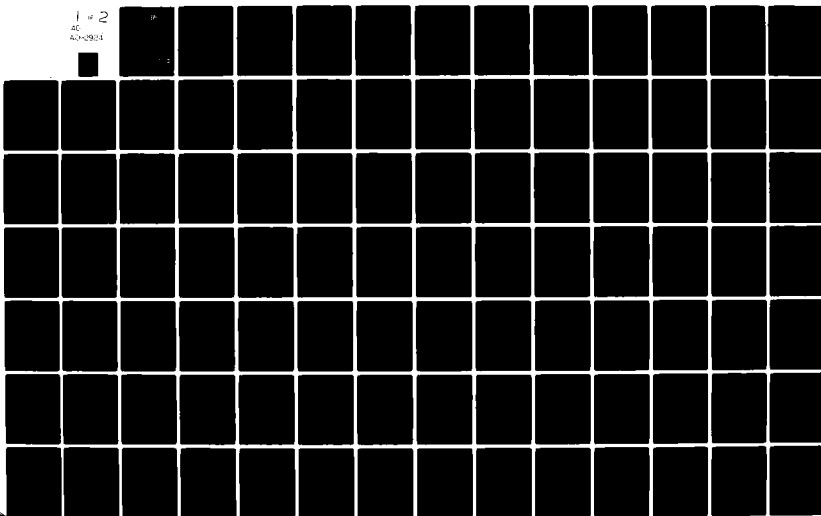
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A LINEAR PROGRAMMING APPLICATION TO AIRCREW SCHEDULING

② LEVEL III

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE

by

CARLTON L. PANNELL, MAJ, USAF
B.A., California Western University, 1964

Fort Leavenworth, Kansas
1980

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This study presents an evaluation of the use of linear programming in maximizing aircrew combat readiness by optimizing allocation of training sorties based on current training requirements and individual aircrew capabilities. The research focuses on an A-7D fighter squadron but the general principals are applicable to other fighter units.

This study demonstrates the feasibility of using linear programming and computer assisted techniques to improve the efficiency of allocating training sorties in a fighter squadron. The study also identifies shortfalls in TAC's existing computer systems and lack of necessary programs to measure aircrew proficiency. The conclusion of the study is that while the application of linear programming techniques may improve the overall efficiency of sortie allocation, it is not currently possible to implement such a system without further research and development of supporting systems. Therefore, it is recommended that additional research be devoted to refining the techniques presented in this study for use as computer terminals become available within individual squadrons.

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A Linear Programming Application to Aircrew Scheduling

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6 June 1980

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MASTER OF MILITARY ART AND SCIENCE

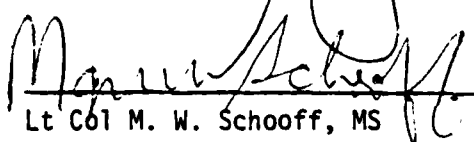
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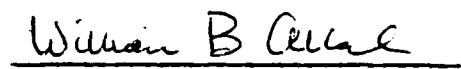
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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

A LINEAR PROGRAMMING APPLICATION TO AIRCREW SCHEDULING, by Major Carlton L. Pannell, USAF, 141 pages.

This study presents an evaluation of the use of linear programming in maximizing aircrew combat readiness by optimizing allocation of training sorties based on current training requirements and individual aircrew capabilities. The research focuses on an A-7D fighter squadron, but the general principals are applicable to other fighter units.

This study demonstrates the feasibility of using linear programming and computer assisted techniques to improve the efficiency of allocating training sorties in a fighter squadron. The research also identifies shortfalls in TAC's existing computer system and lack of necessary programs to measure aircrew proficiency. The conclusion of the study is that while the application of linear programming techniques may improve the overall efficiency of sortie allocation it is not currently possible to implement such a system without further research and development of supporting systems. Therefore, it is recommended that additional research be devoted to refining the techniques presented in this study for use as computer terminals become available within individual squadrons.

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Chapter I

INTRODUCTION

Background

From the late 1960s until the termination of the Vietnam conflict, numerous deficiencies existed in training of Tactical Air Command (TAC) aircrews. Aircrews were sent into combat with little experience in their assigned aircraft and with little or no specialized mission training. (22:5) TAC recognized aircrew training programs required revision and in 1972 conducted a Tactical Fighter Symposium to study the problems and develop recommendations to improve the situation. (22:8)

In 1973, a conference was held at Headquarters United States Air Force to evaluate a new idea in aircrew training. (22:9) Out of this meeting came the Designed Operational Capability (DOC) concept. This concept directed individual units be assigned specific training missions or DOCs.

In July of the following year, the new training concept was implemented with the publishing of a multi-command 51- series manual. (22:9) The basic manual was divided into individual volumes covering each of the aircraft assigned to the Tactical Air Forces (TAF). The basic volume outlined the flying training program in terms of a multi-level approach to matching available resources and training requirements called a Graduated Combat Capability.

Again in 1976, the Air Force took action to verify the status of aircrew training programs in TAC. Air Force directed the Air Force Inspection System Command (AFISC) to perform a Functional Management Inspection (FMI) to identify aircrew training problems and "zero-in" on areas adversely impacting on the quality of aircrew training. The team visited the Air Staff, five major command (MAJCOM) headquarters, and twenty-four air bases within the TAF. The inspection methods used were questionnaires and in-depth interviews with commanders, staffs, and aircrews. (6:1)

Several complex, interrelated problems concerning aircrew training were surfaced by AFISC. Although these problems had been getting worse for years, the true effects were masked due to the highly qualified aircrews. (6:1) The lower experience levels found in fighter units today, coupled with economic and personnel constraints, have highlighted the need to correct existing deficiencies before too much damage occurred to the overall level of combat readiness. The basic finding of the FMI was that flying units needed tailored training programs optimized to programmed wartime tasks and unique unit situations. (6:2)

Today, Air Force military end strength is at its lowest point since 1950. (15:135) Between 1973 and 1979, the Air Force accounted for over sixty percent of the total Department of Defense (DoD) active military reductions. In addition, over the last ten years Air Force manpower declined by thirty-seven percent while military costs increased by thirty percent. (15:136 and 143) Since 1968, our total force -- Air National Guard (ANG), Air Force Reserve (AFRES), and Active duty -- aircraft inventory has dropped from over 15,000 aircraft to a'most

9,000 aircraft (a reduction of forty-one percent). During this same period, the total number of flying hours was reduced by fifty-eight percent, yet the operating costs increased by seventy-five percent. (15:144)

The TAF is faced with many constraints to providing optimum training to today's fighter force. Fewer resources, budgetary limitations, and lower aircrew experience levels are the main restrictions. As flying hours and training sorties are cut, it becomes imperative to efficiently allocate the available sorties to ensure adequate readiness of the fighting force.

Readiness is a concept that integrates the diverse factors that affect the ability to deploy, engage, and sustain effective combat forces. It starts with the overall availability and proficiency of U.S. fighting men. (18:1)

TAF's aircrew training is a readiness issue which has considerable impact on this nation's combat capability. To satisfy the need for a strong tactical air arm, the TAF developed basic aircrew training programs designed to be tailored to the needs and capabilities of the individual aircrews. My experience has been that too many of the units assigned to TAC try to meet the standards of training manuals, rather than attempt to really tailor the flying training program to the individual's abilities.

Problem Statement

The basic problem then is to develop a system or program which will allow the individual squadron scheduler to allocate available training sorties in a way which will not only meet training guidance but also satisfy the training needs of individual aircrews based on their proficiency. Training sorties are allocated to pilots so they

can attain or maintain proficiency. The allocation process is meant to provide proficient crews and a combat ready squadron. (10:10) The state of combat readiness of the squadron depends on the proficiency of individual pilots. To ensure that each pilot can maximize his proficiency within the constraints of available resources, each pilot must be allocated sufficient sorties to maintain the desired proficiency level. To be effective any system or program must be simple and easy to use. It must be flexible and responsive to the needs of the scheduler since the guidelines and resources which are available to the scheduler change frequently. While there may be many suitable programs or systems which would meet these goals (linear programming, dynamic programming, goal programming, etc.), only one approach will be studied due to the limited time available for research.* Due to the simplicity of a linear programming approach and the availability of software to solve very large linear programming models, this research will focus on the possible use of linear programming as an aircrew scheduling aid.

Objective

The objective of this study is to determine if linear programming can be employed to improve scheduling effectiveness by distributing sorties based on the priorities assigned by the scheduler. Although this study is limited to units possessing the A-7D aircraft, the application of linear programming techniques should be equally valid for units with other tactical weapons systems. To be able to

*A brief discussion of linear programming, dynamic programming, and goal programming can be found in Appendix B.

apply to linear programming techniques, one must be familiar with flying training regulations and scheduling problems.

Flying Training

Multi-command manual 51-50, Tactical Fighter/Reconnaissance

Aircrew Training, establishes the flying training program for TAF aircrews referred to as the Graduated Combat Capability (GCC). (12:1-1)
The GCC concept is a three level approach which attempts to match resources and training requirements. The levels are defined as:

1. Level A. This is the basic mission ready standard, as determined by the MAJCOM, and reflects the minimum level to which a crew must be trained to perform the unit's primary mission.
2. Level B. Additional training required to increase proficiency, lower crew/aircraft attrition, and increase the capability to accomplish the unit's full tasking.
3. Level C. This level represents the complete training program for the unit based on full employment tasking. (12:1-2)

Associated with the three levels of training are three progressive phases which an aircrew transitions. The three phases are defined as:

1. Initial Qualification Training (IQT). The training to initially qualify an aircrew in basic flying duties regardless of the unit's operational mission.
2. Mission Qualification Training (MQT). That training in addition to IQT needed to progress the aircrew to designated mission status.
3. Continuation Training (CT). The training for a qualified aircrew member to maintain mission status... (12:1-2)

Another categorization which must be understood is mission status. Aircrews are either mission ready (MR) or mission support (MS). An MR aircrew is one who can be sent into combat and accomplish

the unit's primary mission without additional training. An MS aircrew is one who maintains basic qualifications, but would not enter combat without additional training to reach MR status. (12:1-3)

Both MR and MS aircrews are further classified by experience level. Aircrews are designated as either experienced or inexperienced based on the number of hours flown and the type of aircraft in which the hours were accumulated. An experienced aircrew must meet the following criteria:

1. 1000 or more total hours flying time and 300 hours minimum in the unit aircraft, or
2. At least 500 hours in the unit aircraft, or
3. 100 hours in the unit aircraft and previously categorized as experienced in a specified tactical aircraft. (12:1-3)

Those aircrews who do not meet the above requirements are designated inexperienced.

The sortie program outlined in multi-command manual 51-50 is built around a minimum and standard sortie basis. The standard sortie program sets forth the optimum requirements which must be flown to maintain an assigned training level. The minimum sortie program establishes the least number of sorties which must be flown to maintain an assigned training status. These two programs are further divided into specific sortie types and events which must be accomplished during each six month training cycle.

The minimum sortie and event requirements for all aircrews flying fighter aircraft are listed in Table 1. (12:1-4) This training should be scheduled to ensure a regular sortie flow is accomplished by individual aircrews. (10:34) A regular or steady flow of training is

needed to keep aircrews from losing proficiency or currency in an event or type of mission. Sorties which must be used to regain currency reduce the number of training opportunities which can be used to complete GCC tasking.

Table 1
Semiannual Requirements

Crew Position	Instrument Penetrations	Precision Instrument Approaches	Nonprecision Approaches	Night Landings	Night Sorties	Minimum Total Sorties	Air Refueling MR/MS
Pilot	6	12	12	2	2	30	3/2

With the minimum sortie requirements established, the next consideration is the standard sortie program which establishes the specific guidance for developing unit training programs. Since this study concentrates on an A-7D unit, Table 2 presents an illustrative active duty A-7D training program extracted from TAC Manual 51-50, Vol III. (13:3-3)

Table 2
Active Duty A-7D Training Program

<u>Sorties</u>	<u>Level A</u>		<u>Level B</u>	<u>Level C</u>	
	Day	Night		Day	Night
WD/SAT ^a	22/18	6	11/6	1	9/5
Maverick ^b	6		4/2	2	
SAR ^c			(8/6)	(2)	
ACBT ^d	6		4/2	2	
Subtotal GCC	34/30	6	19/10	14/10	
Total GCC	40/36		59/46	73/56	
Total	50/46		71/57	86/68	

Note: See Appendix A for an explanation of the sortie types.

- a. Weapons Delivery/Surface Attack Tactics
- b. Sorties employing captive or live Maverick air-to-ground missiles
- c. Search and Rescue
- d. Air Combat Training

The numbers under the columns labeled Level A, Level B, and Level C in Table 2 are broken out according to the requirements for inexperienced/experienced aircrews respectively. Level A shows the minimum sorties needed to maintain an MR status. Level B lists the added sorties recommended by TAC when a unit can provide more sorties than required to maintain Level A. Level C includes the remaining sorties to meet TAC's overall training goal. While the subtotal and total GCC tasking is self-explanatory, the difference between total GCC and total sorties is not readily apparent. This difference results from the addition of collateral sorties to the GCC requirements to cover unprogrammable requirements.

Collateral sorties are additional sorties which are used for planning purposes to allow for training directed by Air Force requirements (checkrides, deployments, etc.), upgrade sorties, recurrency

sorties, and non-effective GCC training sorties. For computational purposes, collateral sorties are determined by taking ten percent of the total GCC sorties and adding six more sorties. (12:4-4) Table 3 illustrates the computation of total planning sorties.

Table 3
Collateral Sortie Computation

<u>Total GCC Sorties + Collateral Sorties = Total Planning Sorties</u>		
15-24	8	23-32
25-34	9	34-43
35-44	10	45-54
45-54	11	56-65
55-64	12	67-76
65-74	13	78-87
75-84	14	89-98
85-94	15	100-109

Flying the total number and type of sorties listed in Table 2 is insufficient in itself to maintain a given aircrew status. Aircrews must also meet the GCC event training program requirements. The event training program sets a qualification or proficiency level and a minimum number of event repetitions which must be attained. Of the events required, the weapons delivery qualification is the most important.

To establish and maintain a weapons delivery qualification, an aircrew must meet the standards for each type of delivery which his level of training dictates. Each type of delivery event has scoring criteria which determines if a given delivery is a hit (qualifying) or a miss (not qualifying). To qualify in a delivery event, a minimum number of hits must be achieved. Additionally, fifty percent of conventional ordnance deliveries and forty percent of Maverick deliveries must be hits. Table 4 shows the minimum required hits per type

delivery event (bombing, strafe, and Maverick) based on the type of range used for scoring the delivery. (12:5-5)

Table 4
A-7D Required Hits

<u>Type Event/Delivery</u>	<u>Hits</u>
Conventional Ordnance	
Conventional Range	6/4
Tactical Range	3/5
TOTAL	9/9
Strafe	
Conventional Range	6/4
Tactical Range	-
TOTAL	6/4
Maverick	6
TOTAL	6

Note: Hits are listed in order for inexperienced/experienced pilots.

To illustrate qualification requirements, an example using an experienced aircrew on a conventional range, dropping conventional ordnance will be presented. If the experienced aircrew were to drop four qualifying bombs consecutively, he would be qualified, since he achieved the minimum number of qualifying deliveries by Table 4. However, if the same aircrew were to have four consecutive misses, he would then have to drop at least four more bombs, all hits, to reach fifty percent hits and therefore be qualified.

Requirements of the GCC event training program vary just as the sortie program depending on the level of training assigned. The specific requirements based on Levels A, B, and C are listed in Table 5. There are additional constraints not apparent from looking at the table. First, night events listed in Table 5 are only required

Table 5

A-7D GCC Event Training Program (13:3-5)

Event	Level A		Level B		Level C	
	Day	Night	Day	Night	Day	Night
Computed Low Angle Strafe	Qual					2
Computed Low Angle Bomb	Qual					2
Computed Low Angle Low Drag	Qual	Fam			Qual	Qual
Computed Dive Bomb	Qual	Fam			Fam	Fam
Computed High Altitude Dive Bomb					Fam	Fam
High Angle Strafe						
Flare Delivery		1(Opt)				
Air Support Radar Team Delivery						
Low Level Visual Navigation	6		2		1	
Night/Tactical/Radar Navigation		1			3	
Surface Attack Tactics with FAC	2	1(Opt)	2		1	2
Surface Attack Tactics Alert			2		2	
Maverick			Qual			
Full Scale Weapons Delivery			1		1	
Composite Force Training			2		1	
Radar Deliveries (Day or Night)		1				1
Electronic Warfare Range Training	12					2
Search and Rescue			2		1	
Helicopter Escort			2		1	

Notes.

1. Qual means qualification is required.
2. Fam means that the aircrew is to be familiar with the event but qualification in the event is not required.
3. Opt means the event is optional.

if the unit is tasked to maintain a night capability. Second, deliveries performed during WD sorties and/or SAT sorties, either day or night, may be counted for WD qualifications. Lastly, at least two deliveries in each weapons event must be performed in a manual mode.

Scheduling

Squadron schedulers face a difficult job. (24:40) They must attempt to maximize crew proficiency, morale, and safety while ensuring available resources are neither over nor under used. Schedulers must function in a very fluid environment where availability and priorities of individual aircrews, training areas, suitable weather conditions, and aircraft compound the problem of achieving training objectives. When the scheduler looks at aircrew availability he must consider several factors including the number of aircrews involved, their experience level, priorities of individuals, and the frequency of personnel turnovers.

The aircrews assigned to a squadron are based on the number of aircraft the unit is authorized. Air Force Pamphlet 173-13, USAF Cost and Planning Factors, sets the ratio of aircrews to aircraft. For an A-7D unit the aircrew/aircraft ratio is 1.25 to 1.0. Table 6 shows the relationship for two normal sized squadrons. (8:156 and 159)

Table 6

Aircrew/Aircraft Planning Factors

Type of Aircraft	Aircraft Authorized	Manning Ratio	Authorized Aircrews	Staff	
				Active	ANG
A-7D	24	1.25	30	7	13
A-7D	18	1.25	23	-	13

Based on an active duty A-7D unit with twenty-four aircraft and a 1.25 manning ratio, the scheduler would be working with thirty primary aircrews and seven staff aircrews. Assuming a forty percent experienced ratio for aircrews, the squadron would be made up of twelve experienced primary aircrews and eighteen inexperienced primary aircrews.* The seven staff aircrews would normally meet the requirements for designation as experienced aircrews.

Although the number and experience level of assigned aircrews is a basic consideration, it is still necessary to determine or establish the priority which each aircrew should be given when allocating available sorties. The GCC program provides priority to inexperienced aircrews over experienced aircrews but leaves any other guidelines to be established by the unit commander. This aspect becomes critical when there are insufficient sorties for each member of the unit to meet the training standards and some of the aircrews need extra training to achieve required standards.

Today, personnel policies provide for stabilized three year tours at most bases. To the scheduler this means the unit will lose, on the average, one-third of its members each year. For planning purposes, this turnover equates to five new aircrews per six month training cycle.

The unit training program must efficiently transition new aircrews from IQT through MQT and into CT in as brief a period as

*In Volume III of the Rated Distribution and Training Management Executive Committee Minutes (published semiannually) the aircrew experience ratio is addressed by base and weapons system. While the ratio varies from unit to unit, the ratio for TAC, as a whole, is close to 40/60.

possible. To accomplish this task, the scheduler must be familiar with the requirements and time constraints associated with each phase of training (IQT, MQT, and CT).

The IQT program consists of ten base sorties; however, more sorties may be flown if needed. The first eight sorties are prerequisites for the initial qualification/instrument check on the ninth sortie. The tenth sortie is a night transition sortie which may be accomplished in conjunction with the night sortie in the MQT phase. All ten sorties must be flown with an IP and completed in less than two months. (13:1-1 - 1-4)

Upon completion of IQT aircrews may enter MQT or CT depending on the final status (MR/MS) to be achieved. Aircrews expected to maintain an MS status do not have to complete MQT. The number of sorties to be flown during MQT is determined by the unit commander based on the upgrading aircrew's experience, the assigned GCC level, and ensuring training continuity. The MQT phase must be completed within a two month time frame. (12:3-1 - 3-3)

To enter CT aircrews must have completed IQT and MQT or equivalent training. Since specific CT requirements were discussed in the previous section, the requirements will not be repeated here. It is important to note that it may take at most four months to complete both IQT and MQT which would leave two months of CT to be accomplished.

The CT requirements can be prorated based on the following formula:

$$\frac{\text{Months available}}{6} \times \frac{\text{Events/sorties/hours required per six month}}{1} = \text{Prorated Requirement}$$

Fractions of .5 or greater will be rounded to the next larger number. Those fractions less than .5 will be dropped. (12:1-5) An individual who has only two months left in the training cycle would have to complete one-third of the CT requirements.

In addition to normal training sorties, aircrews must take an annual instrument and qualification checkride. These checkrides must be accomplished with a Standardization/Evaluation Flight Examiner (SEFE). This requirement results in a need for thirty-seven or more sorties per training cycle. Additional sortie requirements result from the various upgrade programs (flight lead, instructor pilot, etc.).

The next major area facing the scheduler is the availability of training areas. There are very limited numbers of low level training routes, weapons ranges, and airspace for air-to-air work which individual units can use on a daily basis. Most of these training areas must be shared with other units which limits the number and type of sorties which can be flown each day by any one unit. Additionally, weather may preclude use of an area even if it was available to the unit.

Weather is an important factor in developing any flying schedule. TAC Manual 25-5, Programmed Flying Training Factors, provides the scheduler with charts on the expected days suitable for flying at specific bases. (11:A5-1 - A5-5) The local weather officer is also important as a source for historical data on both seasonal and daily weather conditions. Knowledge of the weather is critical because it determines not only if flying is possible, but when flying can be accomplished, what areas can be used, and what type of mission can be flown.

The type and number of available sorties is also dependent on the maintenance capabilities of the unit. With a squadron of twenty-four aircraft, fifteen aircraft would normally be flyable to meet the daily flying schedule. Normal use rates would provide about twenty-two sorties per day.*

In addition to the factors which limit the amount of training which can be accomplished, the scheduler must be aware of the need to maintain accurate records of completed training so that requirements can be forecast. Tracking of training accomplishments and currency is a considerable task. Recognizing the benefits to be gained by employment of an automated system to perform these tasks, the MAJCOMs developed and implemented their own computerized management systems.

Automated Flying Training Management Systems

Today, the Military Airlift Command (MAC) has its Automated Resources Management System (MACARMS), the Strategic Air Command (SAC) has its Automated Resources Management System (SACARMS), and TAC has its Automated Flying Training Management System (TAFTRAMS). Actions are underway to combine all of these individual systems into one Air Force wide Operations Resources Management System (AFORMS) in the 1982 time period. Since this study deals with TAC requirements and systems, only TAFTRAMS will be discussed in this section.

*Computation of available aircraft and sortie generation capability is developed in Chapter II on pages 24 and 25.

TAFTRAMS was developed to:

... record and track continuation training activities required by applicable MAJCOM 51-series manuals for use by unit level managers and to support the flow of summarized data to higher headquarters agencies. (14:1-1)

To attain this goal, TAFTRAMS was designated as the official record of CT accomplishments and each unit in TAC was directed to use the system to monitor training directed by MAJCOM 51-series manuals.

TAFTRAMS is a computerized management system developed, tested, and modified by TAC. It is currently a batch processing system run by the local Data Processing Installation (DPI) on Burroughs model 3500/3700/4700 computers. (14:2-4) While the capability to run the system on a daily basis exists, units normally request updates only three times a week. The time span from delivery of the card deck to the data processing center to receiving the computer print-outs is normally overnight.

Computer input data is created from pre-punched or manually punched standard eighty character cards. During a regular cycle up to 5,000 cards can be input. A greater number of cards can be input only with special coordination with the DPI.

Processing time in the Central Processing Unit varies with the

... number of other programs running concurrently in the computer, the number of aircrews, and the amount of data stored for each (i.e., the later in the training cycle, the longer the run time). (14:2-8)

Access to and time on the computer is somewhat determined by the other base agencies which also use the system. Considerable justification is required for any increased use or cost associated with the DPI.

Chapter II

RESEARCH DESIGN AND PROCEDURES

Introduction

The objective of this thesis is to determine if linear programming can be used as a management tool to improve scheduling effectiveness by allocating sorties based on priorities assigned by the squadron scheduler. To determine if linear programming can be used as a scheduling aid, a linear programming model will be developed and used in conjunction with a computer program to generate a squadron sortie allocation for one training cycle. The constraints of the linear model will be modified to evaluate the effects on the sortie allocating process.

This chapter is divided into four subsections. In the first section an imaginary squadron is constructed for use in the linear programming model. Individual pilots are identified with alphanumeric characters and their specific qualifications and characteristics are delineated. In the next section an explanation of the system used to designate the variables in the mathematical model is provided. In the third section the scheduling constraints are developed. The final section illustrates a representative sample of the mathematical relationships which exist based on the considerations of the first three sections.

The Squadron Composition

To formulate the linear program, a basic A-7D unit will be established with current manning factors. This squadron will be based on an active duty squadron with twenty-four aircraft. Manning for the squadron will be based on guidelines found in Air Force Pamphlet 173-13, USAF Cost and Planning Factors, which are summarized in Table 6, page 12. The squadron will consist of thirty primary pilots. Twelve of the thirty pilots would be experienced and the remaining eighteen would be inexperienced. Of the twelve experienced pilots, three will be designated as instructor pilots (IPs). In addition to the thirty primary pilots, there will be seven staff pilots. All seven of the staff pilots will be considered experienced. Three of the staff will be IPs (one of the IPs will be a SEFE) and the remaining four will be MS pilots. Table 7, page 21, provides a summary of the applicable pilot categorizations.

Since each pilot is unique and possesses distinct abilities, it is possible to develop programs to rank the pilots according to their proficiency in comparison with other unit pilots. Some objective programs already exist to rank pilots (such as TOP GUN competition) and some programs will have to be developed.* Where objective measurement systems do not currently exist, subjective rankings could be used with

*TOP GUN competition is a common practice in TAC fighter squadrons. While there are many variations, the pilots are ranked in each weapons delivery event according to their number of hits and/or average miss distance from the target.

only a marginal degradation in results.* To develop rankings for this imaginary squadron a monte carlo simulation approach was used.** A randomly generated number was assigned to each pilot and the resultant distribution was then employed to artificially order the pilots from top to bottom. An unweighted ranking from each type sortie was used to determine an overall position within the squadron. These rankings are depicted in Table 8, page 22.

Definitions of Variables

The variables for this problem represent the number of each type sortie flown by each unit pilot under its current GCC tasking. Each of the thirty-seven pilots assigned to the squadron may fly seven different types of sorties resulting in a total of 259 variables. The general notation for the variables is XPPSS, where PP is the pilot number and SS is the sortie type.*** The alphanumeric designators for the variables are listed for each pilot in Appendix C.

*If each of the squadron IPs subjectively rank all of the pilots in each type of sortie and a composite ranking is developed from these separate lists, the relative pilot rankings are not likely to significantly differ from a ranking developed through a very systematic approach.

**For a discussion of monte carlo simulation the reader should consult Modern Elementary Statistics by John E. Freund or An Introduction to Quantitative Methods for Decision Making by Richard E. Trueman.

***The numeric designators for the various sorties are: 01 (WD), 02 (SAT), 03 (MAV), 04 (ACBT), 05 (SAR), 06 (NIGHT), and 07 (COLS).

Table 7
Pilot Categorization

Pilot Designator	Primary Aircraft		Staff		Experience Level		Instructor Pilot
	MR	MS	MR	MS	Exper/Inexper		
P1				X	X		
P2	X					X	
P3	X				X		
P4	X					X	
P5	X				X		X
P6	X				X		
P7	X				X		
P8				X	X		
P9	X				X		X
P10	X					X	
P11	X					X	
P12	X					X	
P13			X		X		X
P14	X				X		
P15	X					X	
P16			X		X		X
P17	X					X	
P18	X				X		
P19	X					X	
P20	X					X	
P21			X		X		
P22	X					X	
P23	X				X		X
P24	X					X	
P25	X					X	
P26	X					X	
P27				X	X		
P28	X					X	
P29	X					X	
P30	X				X		
P31	X				X		
P32	X					X	
P33	X				X		
P34	X					X	
P35	X				X		
P36			X		X		X
P37	X					X	

Table 8
Pilot Ranking

Group*	Ranking	Type Sortie					Overall Position
		WD	SAT	MAV	ACBT	SAR	
I	1	P14	P23	P36	P10	P26	P23
	2	P16	P9	P13	P18	P3	P9
	3	P9	P18	P9	P13	P16	P5
	4	P32	P11	P14	P5	P23	P14
II	5	P11	P31	P18	P37	P37	P7
	6	P7	P7	P17	P30	P33	P18
	7	P5	P5	P29	P19	P21	P16
	8	P23	P14	P32	P26	P35	P33
	9	P31	P33	P23	P6	P28	P3
	10	P19	P2	P24	P9	P34	P29
	11	P2	P29	P35	P23	P36	P31
III	12	P27	P27	P20	P12	P7	P13
	13	P35	P28	P7	P3	P2	P6
	14	P17	P4	P4	P32	P5	P36
	15	P20	P13	P6	P29	P11	P26
	16	P3	P36	P27	P31	P15	P32
	17	P24	P3	P33	P4	P22	P37
	18	P15	P20	P15	P15	P6	P11
	19	P25	P6	P5	P33	P20	P4
	20	P29	P22	P1	P16	P30	P2
	21	P26	P16	P37	P2	P24	P20
	22	P6	P30	P28	P22	P12	P35
	23	P34	P25	P12	P36	P31	P15
	24	P33	P10	P30	P1	P19	P19
	25	P4	P17	P26	P25	P32	P28
	26	P10	P34	P16	P24	P14	P25
IV	27	P12	P21	P19	P14	P17	P17
	28	P18	P35	P31	P34	P29	P30
	29	P28	P12	P3	P20	P9	P24
	30	P8	P26	P25	P7	P13	P12
	31	P1	P37	P21	P11	P18	P10
	32	P13	P15	P8	P28	P4	P34
	33	P36	P8	P11	P8	P25	P22
V	34	P37	P1	P10	P35	P8	P27
	35	P30	P32	P22	P27	P10	P21
	36	P22	P24	P34	P17	P27	P1
	37	P21	P19	P2	P21	P1	P8

*Use of this column is addressed on page 26.

Constraints

The constraints which the scheduler faces fall into four categories: (1) the number of sorties which can be supported by the available aircraft, (2) the number of each type of sortie which can be supported with other resources, (3) training requirements from applicable guidance, and (4) the training required due to individual pilot proficiency.* These constraints will be covered in order and the mathematical relationships will be developed using the variables listed in Appendix C.

The first consideration is the total number of sorties available from the twenty-four assigned aircraft. TAC Manual 25-5, Programmed Flying Training Factors, provides the basic standards used for computations involved in determining sortie availability.** Two factors are needed, the number of flying days available and the number of sorties which can be flown per day. Figure 1 shows the computation of available flying days for planning purposes. This data is combined with the data in Figure 2 which shows the computation of the number of sorties available per day to determine the total sorties available. When the data from these two figures are combined it can be determined that 2,024 sorties would be available in the

*The variability of weather conditions and availability of the areas from one location to another will not be specifically covered but are usually taken into account when determining the total number and type of sorties available for planning.

**The computation of available flying training days is covered in Attachment 5 and the computation of aircraft utilization and generation rates is covered in Attachment 10 of the manual.

first training cycle (January - June) and 2,464 during the second training cycle (July - December) for a total of 4,488 for the year.

Number of Days Available (January - June)	181	
Less:		
Weekends	52	
Holidays	3	
Weather Days	<u>34</u>	
		<u>89</u>
Number of Flying Days Available First Training Cycle		92
Number of Days Available (July - December)	184	
Less:		
Weekends	43	
Holidays	6	
Weather Days	<u>23</u>	
		<u>72</u>
Number of Flying Days Available Second Training Cycle		<u>112</u>
Number of Flying Days Available Both Training Cycles		204

Figure 1
Available Flying Days

Number of Aircraft Assigned	24	
Less:		
NORM G ^a	24% ^c = 5.76	
NORS G ^b	5% ^c = <u>1.20</u>	
		<u>6.96</u>
Flyable Aircraft		17.04
Flyable Aircraft		
Less:		
Non Mission Capable Aircraft	2% ^c = .34	
		<u>.34</u>
Mission Capable Aircraft		16.70
Mission Capable Aircraft		
Less:		
Load Crew Training	4% ^c = .96	
QC Inspections	10% ^d = <u>.114</u>	
		<u>1.07</u>
Available Flyable Aircraft per Day		15.63
Gross Sorties per Day = (Sortie Rate)(Available Aircraft)		
= (1.446)(15.63) =		22.6
Less:		
Non Delivered Aircraft	2% ^c = .45	
		<u>.45</u>
Net Sorties Available per Day for Planning		22.15

Figure 2

Available Sorties per Day

- a. Aircraft grounded for maintenance.
b. Aircraft grounded for supply.
c. These factors are based on programmed maintenance data and should be verified with a unit's historical records.
d. QC Aircraft/Day = $\frac{(\text{Possessed Aircraft/Mo})(\text{QC Rate})}{\text{Duty Days/Mo}} = \frac{(24)(.10)}{21} = .114$

The next constraint is based on the total number of each sortie type which can be supported with available resources. The restriction could be due to the availability of training ordnance or training areas. This constraint does not apply to collateral sorties. Table 3, page 9, shows the relationship of collateral sorties to GCC sorties. From this relationship it can be determined that the minimum number of collateral sorties for planning would be 222 (six sorties per pilot). The maximum number of collateral sorties for planning would be 222 plus ten percent of the total number of GCC sorties flown.

The next step is to develop a list of constraints based on current training guidelines. By combining the requirements from applicable training directives, the commander's direction, and research of historical records, tables can be set up to identify both minimum and maximum sortie constraints. Table 9 shows the maximum sortie constraints and Table 10 shows the minimum sortie constraints for Level C. Each unit would need to develop similar tables based on their unique situations for each level of training.

Table 9
Maximum CT Sortie Requirements

Status	WD	SAT	MAV	ACBT	SAR	NIGHT	TOTAL
MR EXP	12	13	10	10	8	11	76
MR INEXP	14	20	12	12	10	15	97
MS	6	10	6	6	5	6	39

Notes.

1. MR staff flies at ninety percent of MR EXP level.
2. CT sorties for IQT/MQT pilots will be a prorated share of the Level A requirements.

Table 10
Minimum CT Sortie Requirements

Status	WD	SAT	MAV	ACBT	SAR	Night	Total
MR EXP	5	5	3	4	6	4	64
MR INEXP	7	4	4	6	6	4	83
MS	2	2	2	2	2	2	30

Notes.

1. MR staff flies at ninety percent of MR EXP level.
2. CT sorties for IQT/MQT pilots will be a prorated share of the Level A requirements.

The final area of concern is the number of sorties each pilot needs to maintain a given level of proficiency based on his own abilities. To determine the relative proficiency of each pilot a standardized program should be employed to ensure uniform results. Once the pilots are ranked from top to bottom, it is possible to develop and use a simple modification of Table 8, page 22, to provide additional sorties to those pilots with lower proficiency levels. Table 11 is an example of a simple program to allocate additional sorties to the lower ranking pilots. The unit is divided into five groups. The highest group flies at the minimum sortie rate while the lower groups gain additional sorties. The determination of the number of sorties which each group should gain can be determined from historical data in the squadron. For this evaluation, each of the groups will be given one additional sortie.* From Table 10 an experienced MR pilot in

*The selection of additional sorties given to each group should provide a stepped increase which will not result in the maximum sortie constraint being exceeded.

group I would get a minimum of five WD sorties and an inexperienced pilot in this same group would get seven WD sorties. In group II an experienced pilot would get six WD sorties (five sorties from Table 10 plus one sortie from Table 11) and an inexperienced pilot would get eight WD sorties (seven sorties from Table 10 plus one sortie from Table 11). This allocation process provides priority for inexperienced pilots.

Table 11

Minimum Sortie Adjustment Factors

Group	Sortie Rate
I	Minimum
II	Minimum + 1
III	Minimum + 2
IV	Minimum + 3
V	Minimum + 4

In addition to the maximum and minimum constraints, it is possible to simply set a specific level of sorties to be flown by letting the sortie type equal a fixed number (i.e., $WD = 12$). If the total of two sortie types is to remain constant an inverse relationship must be established (i.e., $WD + SAT = 34$). If desired, a given sortie type can be weighted relative to another type by stating the desired ratio (i.e., $WD = 2SAT$).

Linear Equations and Inequalities

In this section the foundation on which the linear programming model is based is developed. The objective statement, the constraints on the number of each type sortie, and constraints for a representative sample of pilots are developed.

The goal of the scheduler is to maximize the unit's combat readiness by optimizing the allocation of sorties so that no resources will be wasted. To meet this goal, the constraints developed for each pilot will provide a means by which sortie allocation can be efficiently accomplished. The objective function then becomes to minimize the use of resources. The objective function can be expressed as:

$$\text{Minimize } Z = X0101 + X0102 + X0103 + \dots + X3705 + X3706 + X3707$$

The next area of concern is the development of constraints for each sortie type. This would normally be based on local conditions as discussed in the section on constraints. However, since this is not realistic with the imaginary squadron, the constraints were developed using Table 9, page 26, and Table 7, page 21. The results are summarized in Table 12.

From Table 12, the following constraints can be established for each type sortie:

- (1) $X0101 + X0201 + X0301 + \dots + X3501 + X3601 + X3701 \leq 462$
- (2) $X0102 + X0202 + X0302 + \dots + X3502 + X3602 + X3702 \leq 551$
- (3) $X0103 + X0203 + X0303 + \dots + X3503 + X3603 + X3703 \leq 362$
- (4) $X0104 + X0204 + X0304 + \dots + X3504 + X3604 + X3704 \leq 357$
- (5) $X0105 + X0205 + X0305 + \dots + X3505 + X3605 + X3705 \leq 313$
- (6) $X0106 + X0206 + X0306 + \dots + X3506 + X3606 + X3706 \leq 411$
- (7) $X0107 + X0207 + X0307 + \dots + X3507 + X3607 + X3707 \leq 522$

With the constraints established for the individual sortie types, the next consideration is to establish a series of constraints for a representative sample of the pilots typically found in a unit. To accomplish this task, examples will be provided using pilots P1, P2, P3, P16, and P17.

Table 12
Sortie Distribution

PILOT	WD	SAT	MAV	ACBT	SAR	NIGHT	COLS	TOTAL SORTIE
P1	6	10	6	6	5	6	0	39
P2	14	20	12	12	10	15	14	97
P3	12	13	10	10	8	11	12	76
P4	14	20	12	12	10	15	14	97
P5	12	13	10	10	8	11	25	89
P6	12	13	10	10	8	11	12	76
P7	12	13	10	10	8	11	12	76
P8	6	10	6	6	5	6	0	39
P9	12	13	10	10	8	11	25	89
P10	14	20	12	12	10	15	14	97
P11	14	20	12	12	10	15	14	97
P12	14	20	12	12	10	15	14	97
P13	11	12	9	7	7	10	25	81
P14	12	13	10	10	8	11	12	76
P15	14	20	12	12	10	15	14	97
P16	11	12	9	7	7	10	25	81
P17	13	7	5	6	8	14	18	61
P18	12	13	10	10	8	11	12	76
P19	14	20	12	12	10	15	14	97
P20	14	20	12	12	10	15	14	97
P21	11	12	9	7	8	10	9	65
P22	13	7	5	6	8	4	18	61
P23	12	13	10	10	8	11	25	89
P24	14	20	12	12	10	15	14	97
P25	14	20	12	12	10	15	14	97
P26	14	20	12	12	10	15	14	97
P27	6	10	6	6	5	6	0	39
P28	14	20	12	12	10	15	14	97
P29	14	20	12	12	10	15	14	97
P30	15	10	6	6	8	3	16	64
P31	12	13	10	10	8	11	12	76
P32	14	20	12	12	10	15	14	97
P33	12	13	10	10	8	11	12	76
P34	13	7	5	6	8	4	8	51
P35	16	12	7	7	8	3	9	62
P36	11	12	9	7	7	10	25	81
P37	14	20	12	12	10	15	14	97
TOTALS	462	551	362	357	313	411	522	2,978

Pilot P1 is an MS staff pilot. The constraints applicable to

P1 are:

- (8) $X0101+X0102+X0103+X0104+X0105+X0106+X0107 \leq 39$
- (9) $X0101+X0102+X0103+X0104+X0105+X0106+X0107 \geq 30$
- (10) $X0101 \leq 6$
- (11) $X0101 \geq 2$
- (12) $X0102 \leq 10$
- (13) $X0102 \geq 2$
- (14) $X0103 \leq 6$
- (15) $X0103 \geq 2$
- (16) $X0104 \leq 6$
- (17) $X0104 \geq 2$
- (18) $X0105 \leq 5$
- (19) $X0105 \geq 2$
- (20) $X0106 \leq 6$
- (21) $X0106 \geq 2$
- (22) $X0107 \leq 9$
- (23) $X0107 \geq 0$

Pilot P2 is an inexperienced MR pilot. The following constraints

apply:

- (24) $X0201+X0202+X0203+X0204+X0205+X0206+X0207 \leq 97$
- (25) $X0201+X0202+X0203+X0204+X0205+X0206+X0207 \geq 83$
- (26) $X0201 \leq 14$
- (27) $X0201 \geq 8$
- (28) $X0202 \leq 20$
- (29) $X0202 \geq 15$
- (30) $X0203 \leq 12$
- (31) $X0203 \geq 8$
- (32) $X0204 \leq 12$
- (33) $X0204 \geq 8$
- (34) $X0205 \leq 10$
- (35) $X0205 \geq 8$
- (36) $X0206 \leq 15$
- (37) $X0206 \geq 6$
- (38) $X0207 \leq 14$
- (39) $X0207 \geq 8$

Pilot P3 is an experienced MR pilot. The following constraints

apply:

- (40) $X0301+X0302+X0303+X0304+X0305+X0306+X0307 \leq 76$
- (41) $X0301+X0302+X0303+X0304+X0305+X0306+X0307 \geq 64$
- (42) $X0301 \leq 12$
- (43) $X0301 \geq 7$
- (44) $X0302 \leq 13$
- (45) $X0302 \geq 7$
- (46) $X0303 \leq 10$

- (47) X0303 > 6
- (48) X0304 ≤ 10
- (49) X0304 ≥ 6
- (50) X0305 ≤ 8
- (51) X0305 ≥ 4
- (52) X0306 ≤ 11
- (53) X0306 ≥ 6
- (54) X0307 ≤ 12
- (55) X0307 ≥ 6

For an experienced MR IP line 40 would be modified to indicate ≤ 89 , line 41 would be changed to ≤ 77 , line 54 would become ≤ 25 , and line 55 would be ≥ 19 .

Pilot P16 is an MR staff IP. The constraints which apply are:

- (56) X1601+X1602+X1603+X1604+X1605+X1606+X1607 ≤ 81
- (57) X1601+X1602+X1603+X1604+X1605+X1606+X1607 ≥ 56
- (58) X1601 ≤ 11
- (59) X1601 ≥ 6
- (60) X1602 ≤ 12
- (61) X1602 ≥ 7
- (62) X1603 ≤ 9
- (63) X1603 ≥ 5
- (64) X1604 ≤ 7
- (65) X1604 ≥ 4
- (66) X1605 ≤ 7
- (67) X1605 ≥ 5
- (68) X1606 ≤ 10
- (69) X1606 ≥ 5
- (70) X1607 ≤ 25
- (71) X1607 ≥ 19

The last example is pilot P17 who represents a new unit pilot who has completed IQT and MQT in four months and is required to accomplish a prorated share (one-third) of Level A CT sorties. The appropriate constraints are:

- (72) X1701+X1702+X1703+X1704+X1705+X1706+X1707 ≤ 61
- (73) X1701+X1702+X1703+X1704+X1705+X1706+X1707 ≥ 49
- (74) X1701 ≤ 13
- (75) X1701 ≥ 10
- (76) X1702 ≤ 7
- (77) X1702 ≥ 4
- (78) X1703 ≤ 5
- (79) X1703 ≥ 3
- (80) X1704 ≤ 6
- (81) X1704 ≥ 6

- (82) X1705 $\leq$ 8
- (83) X1705 $\geq$ 3
- (84) X1706 $\leq$ 4
- (85) X1706 $\geq$ 2
- (86) X1707 $\leq$ 18
- (87) X1707 $\geq$ 12

With a mathematical model developed for the imaginary squadron, the data can be translated into a format to be processed by a computer using an existing program to solve linear programming models. The computer solution represents a feasible semiannual sortie allocation.* The flexibility and utility of this scheduling technique will be evaluated in the next chapter.

*The computer solution derived for this model was obtained using a Control Data Corporation (CDC) model 6500 computer and the CDC APEX III program.

Chapter III

PROGRAM AND SOLUTION

This chapter is divided into two sections. The first section pertains to the computer program created for this particular research. The second section relates to the solution generated for the mathematical model developed for the imaginary A-7D squadron used as the data base for the problem.

Computer Program

In Chapter II a data base was established and used to develop an LP model. The next step was to write a computer program to simplify transforming the data base into an input for a computer program capable of solving LP problems. The program written for this purpose is listed in Appendix D.

Prior to explaining how the program works it will be necessary to explain some of the terminology used and the arrays or matrixes employed to hold data for processing. To familiarize the reader with the terminology the following definitions are offered:

Terminology	Meaning
P1	A matrix used to hold the input category for each pilot.
P2	A matrix used to hold ranking data for each pilot for each type sortie.
P3	A matrix used to hold total and sortie type maximums and minimums for each pilot (a row from Dimension Table.

RNKRNK	A matrix for holding the pilot's ranking in rank order for each sortie type. For example, if pilot X is ranked first in sortie type J then RNKRNK (1,J)=X.
CUTPER	An array which holds the percentages used to establish the group a pilot would fall into (see Table 8, page 22). Current values are .10, .30, .70, and .90.
CUTPT	An array which holds the numerical cut point determined from the total number of pilots entered and the percentages set in CUTPER.
DIMENSION TABLE	A matrix which holds values for each pilot category entry (currently 21). The values are maximums and minimums for TOTAL, WD, SAT, MAV, ACBT, SAR, NIGHT, and COLS. The columns with negative values reflect variable quantities set by the pilot's ranking in an event. The minus sign is a device used in the computer program to determine if the entry has a fixed or variable value and should not be construed to mean the actual value is negative.
FIXED SET	A value determined by the sign of column in DIMENSION TABLE. The value is TRUE if the sign is positive and FALSE if the sign is negative.
MAXFLT	An array which holds maximum allowed total sorties by sortie type.
RESPNS	An array used to hold input data moved to P1 and P2.
RESPNS(1)	Pilot number.
RESPNS(2)	Training category.
RESPNS(3)	Post training category.
RESPNS(4)	Months to complete training.
RESPNS(5)	Training status after training.
RESPNS(6)	Pilot status.
RESPNS(7)	IP status.
RESPNS(8)	Experience level.
RESPNS(9)	GCC level.
RESPNS(10)	Pilot rank (1).
TOTPLT	Total number of pilots.

MAXPLT	Maximum number of pilots for the program (currently 50).
PNMBR	Pilot number.
TNGCAT	Training category
POSTCT	Post training category (MR or MS).
CATGRY	Category (Primary or Staff).
EXPER	Experience level.
STATUS	Pilot mission status (MR or MS).
ENTRY	Row of DIMENSION TABLE.
POINT	Column to be entered in the DIMENSION TABLE.
BASE	Absolute value of entry in POINT.
BUMP	Amount by which BASE is to be increased.
RERANK	A subroutine used to rerank pilots based on the limitation that each pilot must be allocated at least as many sorties as the next pilot ranked lower in order. Pilots who would violate this constraint are removed from ranking.
RANK	A matrix used to hold initial pilot ranking by type sortie.
RANK(2)	A matrix used to hold pilots after reranking.
MAX	A matrix which holds modified rows of the DIMENSION TABLE.
MAXP	A column in MAX matrix which contains the maximum sortie constraints.
MINP	A column in MAX matrix which contains the minimum sortie constraints.
CARDS	A subroutine used to generate an output format suitable for input into the CDC APEX III program.
CHRRANK	A subroutine used to check the ranks input to ensure they do not exceed number of total pilots or repeat.

The computer program used in this research depends on a simple matrix made up of the upper and lower bounds for each of the different

	MAX SORTIE	MIN SORTIE	MAX WD	MIN WD	MAX SAT	MIN SAT	MAX MAV	MIN MAV	MAX ACBT	MIN ACBT	MAX SAR	MIN SAR	MAX NIGHT	MIN NIGHT	MAX COLS	MIN COLS
1	55	46	8,	-4,	9,	-5,	7,	-3,	6,	-2,	5,	-1,	10,	5,	20,	15
2	72	72	10,	-6,	12,	-7,	7,	-3,	6,	-2,	9,	-5,	7,	5,	21,	16
3	81	75	11,	-6,	12,	-5,	9,	-5,	7,	-2,	9,	-5,	10,	5,	22,	17
4	42	33	8,	-4,	9,	-5,	7,	-3,	6,	-2,	5,	-1,	6,	2,	9,	6
5	56	50	10,	-6,	12,	-7,	7,	-3,	6,	-2,	9,	-5,	7,	5,	10,	6
6	65	59	11,	-6,	12,	-5,	9,	-5,	7,	-2,	9,	-5,	10,	5,	11,	9
7	39	30	6,	2,	10,	2,	6,	2,	6,	2,	5,	2,	4,	2,	9,	6
8	50	40	9,	-5,	9,	-5,	7,	-3,	6,	-0,	6,	-2,	6,	2,	10,	9
9	61	50	12,	-8,	12,	-8,	8,	-4,	6,	-2,	8,	-4,	6,	2,	11,	10
X	76	69	12,	-7,	13,	-8,	10,	-6,	8,	-4,	11,	-7,	11,	6,	2,	10
1	59	49	9,	-5,	9,	-5,	7,	-3,	6,	-0,	6,	-2,	6,	2,	25,	19
2	70	59	12,	-8,	12,	-8,	8,	-4,	6,	-2,	8,	-4,	6,	2,	25,	19
3	89	77	12,	-7,	13,	-8,	10,	-6,	8,	-4,	11,	-7,	11,	6,	25,	19
4	50	36	10,	-6,	12,	-8,	6,	-2,	6,	-0,	6,	-2,	6,	2,	10,	4
5	71	59	10,	-6,	13,	-8,	10,	-6,	8,	-4,	10,	-6,	6,	6,	12,	6
6	97	84	16,	-12,	18,	-13,	12,	-8,	10,	-6,	12,	-8,	15,	6,	13,	8
7	39	30	6,	2,	10,	2,	6,	2,	6,	2,	5,	2,	4,	2,	9,	6
8	69	50	17,	11,	13,	10,	8,	6,	8,	5,	6,	3,	4,	2,	14,	8
9	66	50	16,	10,	12,	9,	7,	5,	7,	4,	6,	3,	3,	2,	13,	9
X	62	60	15,	9,	10,	7,	6,	4,	6,	3,	6,	3,	3,	2,	16,	10
1	57	45	13,	10,	7,	4,	5,	3,	6,	6,	6,	3,	4,	2,	18,	12

Figure 3

Dimension Table

TABLE ENTRY	TNG CTGRY	NEXT STATUS	MONTHS TO COMP	PILOT CTGRY	PILOT STATUS	IP	EXPER	GCC LEVEL
1	CT			STAFF	MR	YES	EXP	A
2	CT			STAFF	MR	YES	EXP	B
3	CT			STAFF	MR	YES	EXP	C
4	CT			STAFF	MR	NO	EXP	A
5	CT			STAFF	MR	NO	EXP	B
6	CT			STAFF	MR	NO	EXP	C
7	CT			STAFF	MS	NO	EXP	
8	CT			PRIM	MR	YES	EXP	A
9	CT			PRIM	MR	YES	EXP	B
10	CT			PRIM	MR	YES	EXP	C
11	CT			PRIM	MR	NO	EXP	A
12	CT			PRIM	MR	NO	EXP	B
13	CT			PRIM	MR	NO	EXP	C
14	CT			PRIM	MR	NO	EXP	A
15	CT			PRIM	MR	NO	EXP	B
16	CT			PRIM	MR	NO	EXP	C
17	IQT/MQT	MS	1				INEXP	A
18	IQT/MQT	MR	2				INEXP	B
19	IQT/MQT	MR	3				INEXP	C
20	IQT/MQT	MR	4				INEXP	
21	IQT/MQT	MR					INEXP	

Figure 4
Dimension Table Key

combinations possible for a squadron assigned to maintain GCC Level C and both NIGHT and SAR capabilities. This matrix is illustrated in Figure 3. Figure 4 shows a key to determine which rows of the matrix relate to which pilot characteristics. As training directives or local standards change, the only action required to update the program is to change the appropriate entry in the matrix to correspond to the new guidance.

Figure 5 illustrates the logic flow within the computer program. The required input data is requested by the program through a series of questions. The actual input data is checked and an error message printed when a discrepancy is noted. As the data is read into the program it is stored in various arrays or matrixes and then processed as required.

The program establishes the sizes of the pilot groups (I, II, III, IV, or V) based on cutpoints which are computed using preprogrammed percentages and the total number of pilots entered into the program. The size of the groups can be altered by changing the percentages stored in CUTPER.

Based on the inputs the program selects the appropriate row from the Dimension Table and saves the information for each pilot. Based on the cutpoints the columns of the Dimension Table that are variable , are adjusted, and the results are again stored. Next, the pilots are reranked by a process whereby the maximum by sortie type of each pilot is compared with the minimum of the next lower pilot. If the lower pilot's minimum is larger than the first pilot's maximum the lower pilot is given a ranking of "0." This results in spaces in the ranking sequence which need to be corrected (i.e., 1, 0, 3, 4, 0, 6).

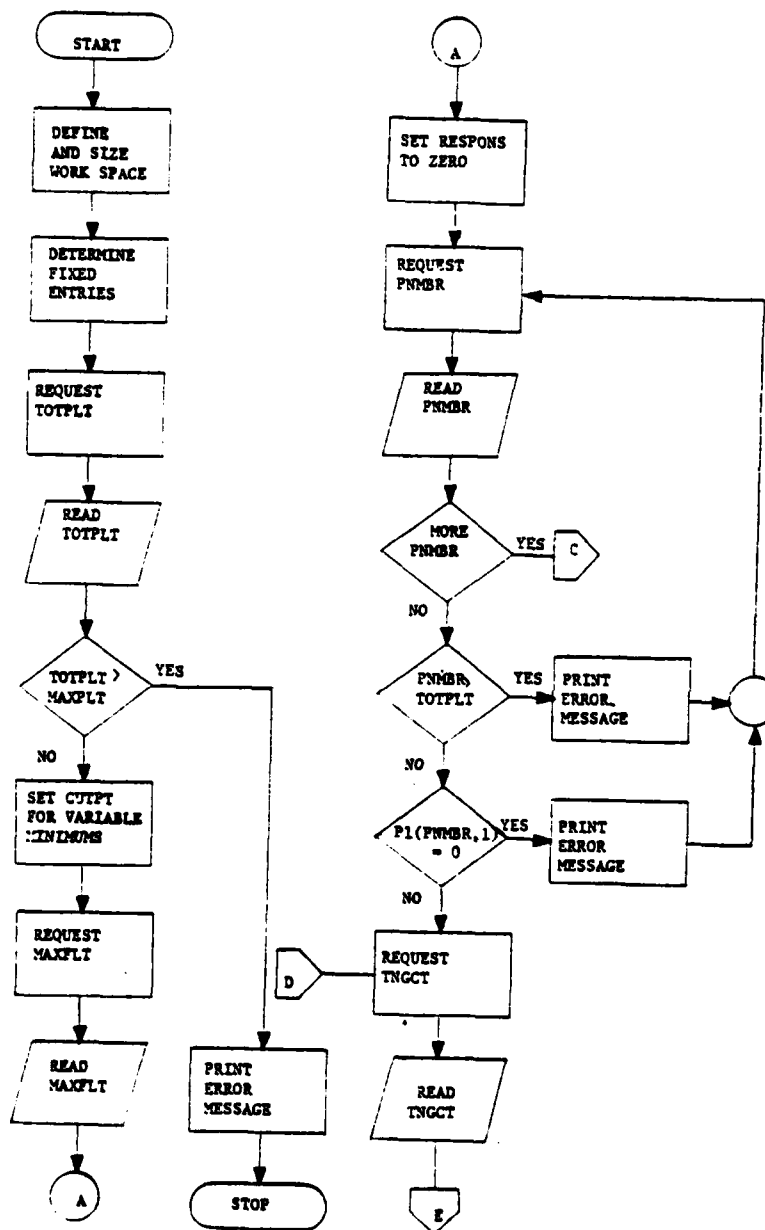


Figure 5
Flow Chart

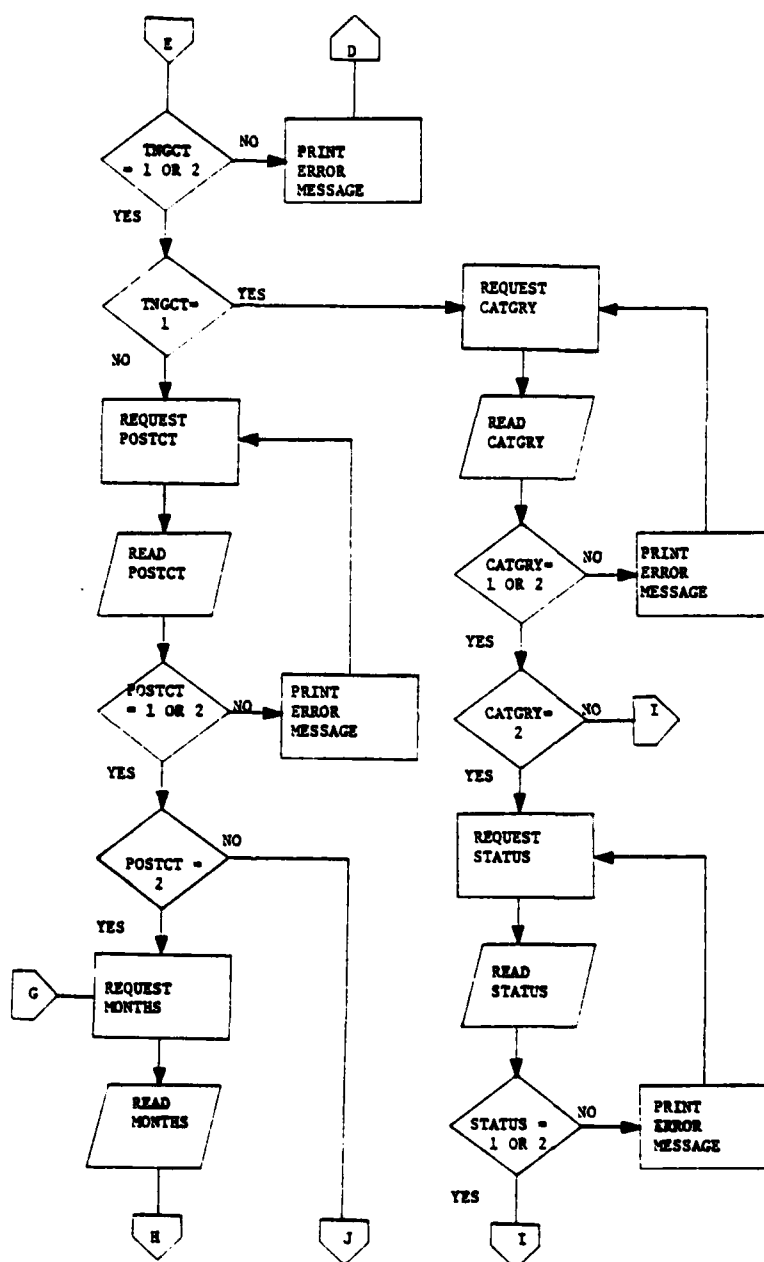


Figure 5 (Continued)

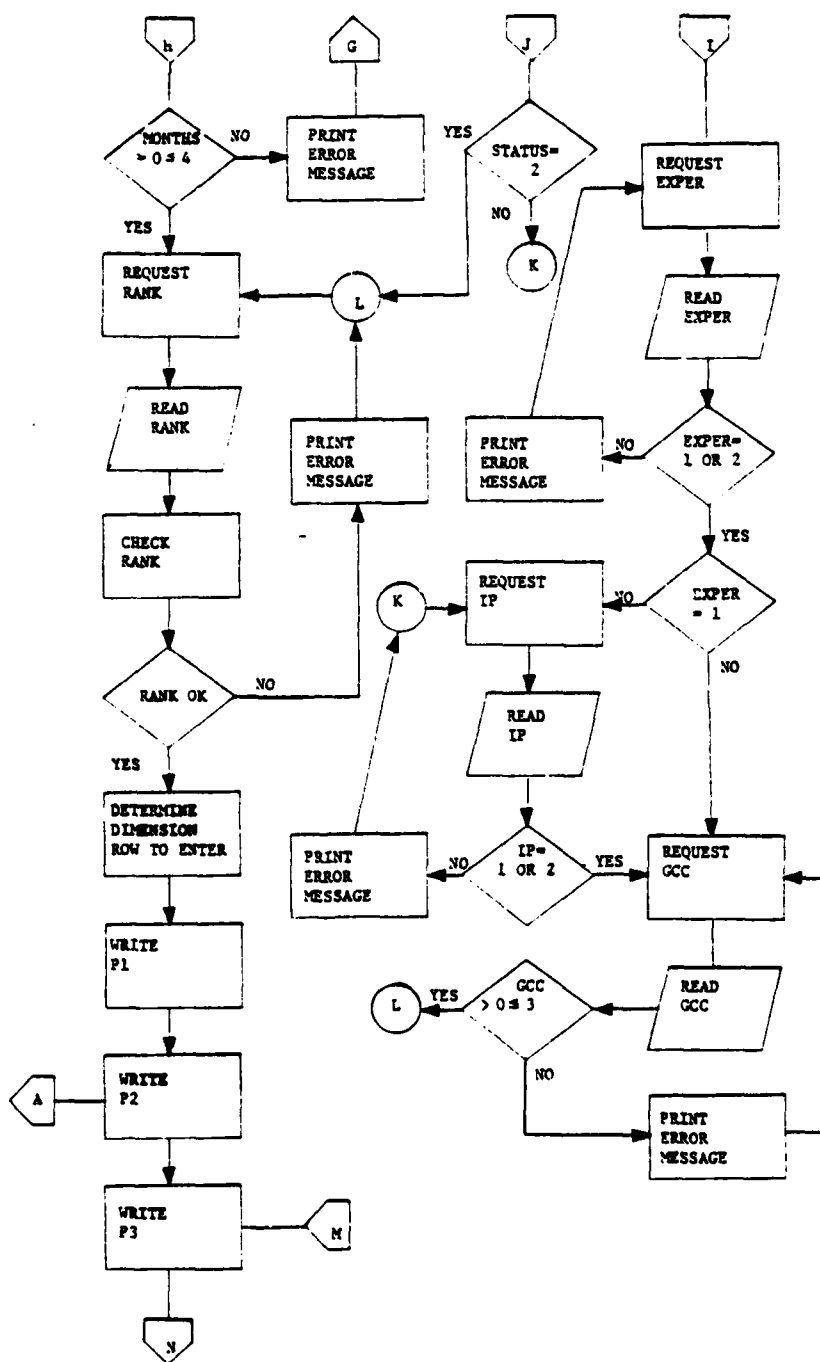


Figure 5 (Continued)

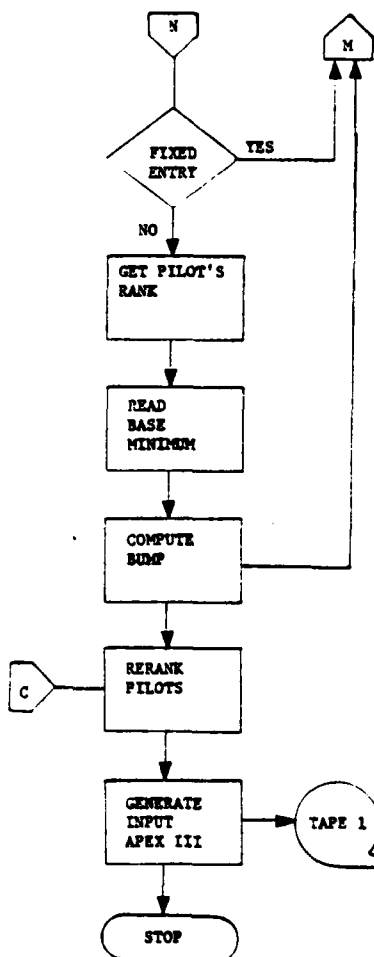


Figure 5 (Continued)

The nonzero entries are renumbered in sequence and the zero entries moved to the end of the matrix (i.e., 1, 2, 3, 4, 0, 0). This process was used to establish the constraint that a pilot should fly fewer sorties than the next lower ranked pilot unless this condition is not feasible due to other considerations (assignment of different GCC levels, mission status, or training category).

The final step in the program is to convert the input data into the proper format for the software package used (in this instance the CDC APEX III package).^{*} The CARDS subroutine accomplishes this task by reading the processed data and generating an output in the general format depicted in Figure 6 on page 45. If a different input format is required for use with other linear programming software packages, the CARDS subroutine would have to be modified.

Further refinements are possible in the program by including additional error checks to make the system foolproof. Also, improvements would be made by adding loops to account for prorating pilots who are not available to fly during the entire training cycle or who are not tasked for both night and/or SAR requirements. Decision on what added capabilities are to be included in follow-on programs should be based on user needs and desires.

Although the original intent of developing the LP model was to minimize the sorties flown, the form of the objective function

^{*}The CDC APEX III package is an optimization program which provides a flexible approach to solving linear or integer programming models. Both the input and output formats used are standardized throughout the computer industry for this type problem. The size of the LP problem which the system can solve is normally limited by the amount of central memory accessible (i.e., 8,190 maximum constraints and 32,760 variables).

makes it possible to run both a maximum and minimum solution to provide the scheduler with more information and a better basis for decision making. The next section provides a discussion of the computer solutions and the information available.

Computer Solution

The computer solution consists of two divisions, the first containing the minimum solution and the second containing the maximum solution. The minimum and maximum divisions are further divided into two sections. The first section, labeled CONSTRAINTS, depicts information on the rows of the solution matrix (listing of total sorties by type and by pilot). The second section, labeled COLUMNS, depicts the information on the columns of the solution matrix (listing by pilot of the number of each type sortie).

The CONSTRAINTS section is further divided into nine columns. These columns are labeled NUMBER, NAME, TYPE, STATUS, ROW ACTIVITY, SLACK, RHS LOWER, RHS UPPER, and MARGINAL.

NUMBER. The entries under this column are all integers. The integers represent the input order for the row.

NAME. The alphanumerics in this column are the row names. The names may be in one of three forms:

TWD	(Total WD sorties)
P01	(Total sorties for pilot 1)
C1416WD	(Constraint on relationship between pilot 14 and pilot 16 WD sorties)

TYPE. Entries in this column indicate the nature of the relationship involved in the LP model. The possible entries include:

EQ	(Equals)
GE	(Greater than or equal)
LE	(Less than or equal)

FR (Free range from $-\infty$ to $+\infty$)

** (An alternate optimal solution exists)

If a row is ranged a B will precede the above designators.*

STATUS. Indicates the basis status of the slack variable.** Entries are:

BINDING (Either there is no slack, or this is a basis status of nonbasic or nonbasic at a bound)

SLACK (There is slack or unused resources. This is a basis status of basic)

ROW ACTIVITY. The sum of the row activity (solution).

SLACK. The value of the difference between the right hand side (RHS) value input and the current ROW ACTIVITY (solution).

RHS LOWER. The minimum value the row sum can have.

RHS UPPER. The maximum value the row sum can have.

*Ranging applies to row (constraints) of the problem and is a positive number which sets the allowable deviation from the RHS value. It serves the same purpose for rows that upper and lower bounds serve for columns.

**Using a simplex tableau made up of a system of m equations and n variables, where m is less than n , let the excess variables ($n-m$) be assigned a value of zero. Then the remaining m equations in m variables have a unique solution such that:

(1) The variables ($n-m$) assigned a zero value are said to be "nonbasic."

(2) The remaining variables (m) are called "basic."

(3) The solution to the tableau is called a "basic solution."
(5: 227-228)

MARGINAL. The shadow price of the row. The value indicates the change in the objective function for a change of one unit in the row. The sign of the MARGINAL value indicates if the objective function will increase or decrease when the row is changed by one unit. If the sign is positive the objective function will worsen and if negative the objective function will be improved.

If the ROW ACTIVITY is less than the RHS LOWER value or greater than the RHS UPPER value, the word INFEASIBLE will be printed on the extreme right hand side of the solution indicating a shortage of sorties. Either additional sorties will have to be made available or a less than optimal sortie allocation will have to be accepted. If the MARGINAL entry is nonzero in value and has an improper sign for the row TYPE and STATUS, the word NONOPTIMAL will be printed on the extreme right hand side of the solution indicating a better solution would be possible if the appropriate bound were changed. No action is required.

The COLUMNS section is divided into nine columns also. These columns are labeled NUMBER, NAME, TYPE, STATUS, COL ACTIVITY, OBJ COEF, BND LOWER, BND UPPER, and MARGINAL.

NUMBER. The integers in this column are the input order of the column entries.

NAME. The alphanumerics in this column are the names given to the columns. The names are in the form

PO1WD (WD sorties allocated to pilot 1)

TYPE. Entries in this column indicate the column relationships. Possible entries include:

PL	(Plus variable)
MI	(Minus variable)
FX	(Fixed variable)
FR	(Free variable)
BV	(Bivalent variable; can be either 1 or 0)
INT	(Integer variable)
**	(Indicates other optimal solutions exist)

For ranged variables a B will precede the above designators.

STATUS. Entries in this column show the basis status of the column.

The status can be:

ACTIVE	(Column is basic)
UPPER	(Nonbasic variable at its greatest value)
LOWER	(Nonbasic variable at its smallest value)

COL ACTIVITY. The value in this column is the column activity level or current solution.

OBJ COEF. Entries in this column give the value of the objective column coefficient. For this solution the value will always be one.

BND LOWER. The smallest value the variable can have.

BND UPPER. The largest value the variable can have.

MARGINAL. The reduced or shadow cost of the variable.

If the value of the COL ACTIVITY is less than BND LOWER or more than BND UPPER the word INFEASIBLE will be printed on the extreme right hand side of the solution. If the MARGINAL value is nonzero and has an

improper sign for the column, the word NONOPTIMAL is printed on the extreme right hand side of the solution.

A review of some specific examples will help to explain how to interpret the data. To do this notional examples will be used for NUMBER entries 5(TSAR), 12(P04), and 48(C0932WD) of the CONSTRAINTS section and NUMBER entry 204(P30WD) of the COLUMNS section.

The original constraint for the total number of SAR sorties was $X0105+X0205+X0305+ \dots +X3505+X3605+X3705 \leq 313$. This condition is reflected in the entries in the nine columns of the CONSTRAINTS section as:

Column	Entry	Meaning
NUMBER	5	TSAR was input number five to program.
NAME	TSAR	Total SAR sorties.
TYPE	LE	Constraint is less than or equal relationship.
STATUS	SLACK	Row sum not equal to RHS UPPER value.
ROW ACTIVITY	355	Total SAR sorties needed for feasible solution.
SLACK	-42	ROW ACTIVITY exceeds RHS UPPER by 42 sorties. Need 42 more SAR sorties for a feasible solution.
RHS LOWER	-INF	Since no bound was specified a $-\infty$ lower limit is implied.
RHS UPPER	313	Initial SAR sorties for planning.
MARGINAL	.	If no value is entered the value is assumed to be zero. The shadow cost is zero.

The word INFEASIBLE printed at the right hand side indicates ROW ACTIVITY value is greater than RHS UPPER value. Forty-two more SAR sorties would be needed for the solution to be feasible.

The original constraints for the maximum and minimum number of sorties pilot 4 (P04) could fly were:

$$X0401+X0402+X0403+X0404+X0405+X0406+X0407 \leq 97 \text{ and}$$

$$X0401+X0402+X0403+X0404+X0405+X0406+X0407 \geq 83.$$

These conditions are reflected in the entries in the nine columns of the CONSTRAINTS section as:

Column	Entry	Meaning
NUMBER	12	P04 was number twelve input to program.
NAME	P04	Total sorties for pilot 4 (P04).
TYPE	BLE	Relationship is a ranged less than or equal constraint.
STATUS	BINDING	Basis status at RHS LOWER value.
ROW ACTIVITY	83	Total sorties allocated to P04.
SLACK	14	Difference between RHS UPPER and ROW ACTIVITY values.
RHS LOWER	83	Minimum sorties for P04.
RHS UPPER	97	Maximum sorties for P04.
MARGINAL	-4	If the number of sorties allocated to P04 was increased the objective function value would increase by 4.

To understand the entries for C0932WD it is necessary to examine the ranking process and the constraint that a pilot should not get more sorties than the pilots ranked lower than him in that type of sortie. For the basic solution, the following conditions were formulated:

Pilot Number	WD Ranking	Lower-Upper Bounds
P09	3	7 - 12
P32	4	12 - 16

For the constraints to hold, if P09WD equaled 12 then P32WD would have to be 12 or more. The difference between P09WD and P32WD would be the slack. Since P09WD is required to be larger or equal to P32WD, the slack must have a negative sign. These conditions are reflected in the entries in the nine columns of the CONSTRAINTS section as:

Column	Entry	Meaning
NUMBER	48	Input was number 48 to program.
NAME	C0932WD	Constraint between P09WD (X0901) and P32WD (X3201).
TYPE	LE	$P09WD \leq P32WD$.
STATUS	SLACK	There is a difference between P09WD and P32WD.
ROW ACTIVITY	-2	P09WD is 2 units less than P32WD.
SLACK	2	Difference between RHS UPPER and ROW ACTIVITY is 2.
RHS LOWER	-INF	Since no lower limit was stated, $-\infty$ is implied.
RHS UPPER	.	Since P09WD is not allowed to be greater than P32WD the maximum value is 0 when the two values are equal.
MARGINAL	.	The shadow value is 0.

From the COLUMNS section the value for P09WD is 11 and for P32WD is 13. Therefore, the slack between P09WD and P32WD is 2.

The final entry to be reviewed is the restriction on P30WD sorties. The original constraints were:

$$X3001 \leq 15$$

$$X3001 \geq 9$$

These conditions are reflected in the entries in the columns of the COLUMNS section as:

Column	Entry	Meaning
NUMBER	204	Input was number 204 to program.
NAME	P30WD	Total WD sorties for pilot 30 (P30).
TYPE	INT	Integer variable.
STATUS	**UPPER	Other optimal solutions exist. Solution is BND UPPER value.
COL ACTIVITY	15	Solution for number of WD sorties allocated to pilot P30.
OBJ COEF	1	Coefficients of WD variables are equal to 1.
BND LOWER	9	Minimum WD sorties for P30.
BND UPPER	15	Maximum WD sorties for P30.
MARGINAL	.	In the current solution there is no reduced costs for variable (X3001).

This chapter has presented an outline of the basic composition of the FORTRAN computer assisted scheduling program and the computer solution print-out. The intent was to familiarize the reader with how the system works and the information available. For a general guide on how to use the system see Appendix G.

Chapter IV

ANALYSIS AND CONCLUSIONS

Resource allocation problems lend themselves to mathematical optimization techniques. This is natural since there exists an objective or goal and various restrictions or constraints. There are both disadvantages and advantages to the application of mathematical techniques in assisting or accomplishing aircrew scheduling.

Disadvantages include the determination of optimality of the schedule generated and the formulation of the numerous constraints and decision variables. Another lesser difficulty could be an inability to quickly modify the basic computer program in the field to account for changes in scheduling priorities as they occur. This problem exists because there are no computer programmers readily available in the field to perform the required modifications. Probably the most limiting factor in the approach presented in this study is the need to rank pilots according to their individual proficiency in different types of sorties. My experience has been that pilots do not like to be ranked against their peers and would be concerned with the other possible uses of such rankings (job selection, OERs, etc.). Further limitations arise since objective measurement systems do not currently exist in some of the areas to provide a measure of individual pilot proficiency.*

*Development of objective measurements of training programs is a subject of continued interest of Headquarters TAC Standardization/Evaluation and is listed as a research topic in the 1979-80 volume of the Air University Compendium of Research Topics.

The advantages of this approach to resource allocation are considerable. Once the basic constraints are identified and expressed in mathematic relationships a linear model can be developed and solved by one of the many LP software packages which are readily available. Flexibility of the system depends primarily on the number of considerations taken into account when developing the basic program. The input program developed for this research clearly indicates the ease with which an interactive program can be produced which will be easy for any scheduler to employ without detailed training in computer languages. The ease with which various combinations can be generated and compared should lead to considerable time savings for the scheduler. Ultimately, the greatest advantage should be the efficient allocation of available training sorties to those who need them the most resulting in a unit with the highest overall proficiency or readiness.

The specific approach studied in this research should prove to be a valuable management tool. The approach can accurately project the training resources needed. It can be used to project requirements by total sorties, total sorties by type, and sorties both total and type for each pilot. In addition, by using both minimum and maximum solutions a range or "delta" for various sortie needs can be forecast. If this approach were combined with a system for prioritizing pilots for flight requirements based on qualification status, currency, quantity of sorties needed, and availability a very powerful computer assisted scheduling program could be generated.

Further research should be directed at the use of linear programming models in computer assisted scheduling modes. As the current

TAFTRAMS is changed from a batch system to an interactive system in the 1982 time frame the use of a system similar to the one developed in this research could be of considerable aid to the scheduler.* The next logical step would be to introduce the use of a goal programming approach into the scheduling process to allow for introduction of a priority goal system.

The current Burroughs Medium Computer system used by TAC was designed primarily for business applications. The system was not designed to perform high level arithmetic or scientific functions. However, the systems can perform these two functions when modified with a floating point adapter. This is a major drawback to implementing the program developed in this research due to the cost of the modification.

Another drawback to using the FORTRAN computer assisted scheduling program is the need for a FORTRAN compiler when using FORTRAN programs. This drawback can be overcome without any additional cost by using the available compilers and rewriting the program in the COBOL language or any other language compatible with the existing compilers.**

The availability of an LP software package which could be used in place of the CDC APEX III package is another area of concern. Burroughs markets a software package named TEMPO. This package is a

*Conversion of TAFTRAMS to an interactive AFORMS system in the 1982 time frame was confirmed as a goal in a conversation with Captain Andy Dorman from TAC DOOTR.

**A compiler is an input device for translating programming languages into a machine language used by the computer for processing.

mathematical programming system which provides a capability similar to the CDC APEX III system. The input and output formats used by both systems are essentially the same. It would take only minor modification to make the FORTRAN computer assisted scheduling program compatible with the Burroughs' TEMPO system.

The major factor remaining then is cost. There are at least four options which could be followed to allow the scheduler access to this type of scheduling assistance each with differing costs. The options are:

1. Modify all existing Burroughs medium systems with the floating point adapter and buy or lease the TEMPO package for each wing size unit.

2. Modify one system at Headquarters TAC, buy or lease the TEMPO package, and provide access to the units assigned to TAC.

3. Develop a suitable integer programming model using TAC resources and modify either one or all of the medium systems with floating point adapters.

4. Purchase a minicomputer for each wing size unit and develop a compatible integer programming software package.

To determine which option is most desirable in terms of a cost/benefit ratio additional analysis would be required at the time implementation of the program is contemplated.

The basic conclusion derived from this research is that while the application of LP models to aircrew scheduling can improve the efficiency of sortie allocation such a system cannot be currently implemented. Additional research will be required to determine the best

method to overcome the existing obstacles so that the benefits to be gained from this application can be realized.

Chapter V

SUMMARY AND RECOMMENDATIONS

The thesis of this research was that linear programming could be used to improve aircrew scheduling procedures by providing an efficient means of allocating available training resources to meet applicable training directives and the proficiency of individual pilots. To evaluate this thesis an imaginary A-7D squadron was established to provide the framework on which to build a mathematical model. The model was created using the general format applicable to linear programming models.

To simplify the transition from the linear programming model to a document which the scheduler could use for sortie allocation, a FORTRAN computer assisted scheduling program was written. This program was set up so that a detailed knowledge of computer programming was unnecessary. Indeed, all the scheduler is required to do is answer questions generated by the program and then tie the program to a computer software package for solving linear programming models.

Evaluation of the computer product indicated significant benefits to be gained in better use of available training resources. No apparent contradictions could be found with the computer product and applicable directives.

Research into the capabilities of the current computer capability possessed by TAC units indicates a degree of modification would

be needed before implementation of the program generated for this research could become a reality. However, the current Burroughs Medium System computer family can be used to perform the higher mathematics involved by addition of a floating point adapter. Furthermore, Burroughs has a current computer software package called TEMPO for the medium system computers which will provide the required LP model solving capability.

The feasibility of using linear programming and computer techniques to assist the scheduler in efficiently allocating training sorties has been adequately demonstrated. However, additional research will be involved before the system can be fielded. Additional work must be accomplished on developing meaningful programs to measure aircrew proficiency so that a suitable ability will exist to objectively rank pilots in the variety of sortie types flown. Also, research will be needed to determine if the cost/benefit ratio is great enough to justify the funds to support conversion of current systems to allow higher mathematical operations. If research into these two areas is positive, then actions should be taken to implement this or a similar follow-on program to assist the scheduler in using our ever dwindling training resources more efficiently.

APPENDIX A

APPENDIX A

DEFINITIONS AND ABBREVIATIONS*

Air-to-Air Refueling (AAR). An event requiring hookup and transfer of fuel between two aircraft in-flight.

Air Combat Maneuver (ACM). Coordinated application of BFM by two or more aircraft to achieve a simulated kill against one or more target aircraft from a preplanned and "canned" position.

Air Combat Tactics (ACT). Application of ACM skills to achieve a tactical air-to-air objective under realistic scenarios.

Air Combat Training (ACBT). A generic term which includes BFM/DBFM, ACM/DACM, ACT/DACT, and DCM where tasked in GCC training.

Air Reserve Forces (ARF). Any of units assigned to the components of the United States Air Force Reserves.

Air Support Tactics (AST). Close air support and air support training missions flown against targets identified by the battlefield commander.

Air-to-Surface Training (A/S). Training which consists of weapons delivery and surface attack sorties.

Basic Fighter Maneuvers (BFM). Basic application of skills in roll, turn, and acceleration singularly or in combination toward one versus one aircraft positioning.

Collateral Sorties (COLS). Sorties in addition to GCC requirements programmed to account for non-effective sorties and training required by Air Force requirements.

Continuation Training (CT). Training flown by MR/MS aircrews to maintain proficiency and meet training requirements.

Dissimilar Air Combat Maneuvers (DACM). ACM flown against one or more aircraft of a different design or series.

Dissimilar Air Combat Tactics (DACT). ACT flown against one or more aggressor aircraft of a different design or series.

Dive Bomb (DB). Delivery of ordnance off an aircraft from a dive angle of thirty degrees or more.

Dissimilar Counter Maneuvering (DCM). BFM flown to negate an air-to-air attack and safely disengage.

Graduated Combat Capability (GCC). A three level concept of managing resources against training requirements.

Instructor Pilot (IP). A pilot selected because of his high experience level and mature judgement to train other pilots.

Initial Qualification Training (IQT). Training flown before a pilot takes his proficiency checkride and enters MQT.

Interdiction Tactics (IT). Tactical sorties flown on interdiction profiles emphasizing employment against preplanned targets.

Low Angle Bomb (LAB). Delivery of a high drag weapon from a dive angle of less than twenty degrees.

Low Angle Low Drag Bomb (LALD). Delivery of a low drag weapon with a dive angle between twenty and thirty degrees.

Low Angle Strafe (LAS). Delivery of 20/30 mm ordnance on a surface target with a dive angle of less than twenty degrees.

Mission Qualification Training (MQT). Training following IQT which prepares aircrews for their initial qualification checkride and entry into CT.

Mission Ready (MR). Status of an aircrew who meets GCC training requirements. The aircrew could enter into combat without further training.

Mission Support (MS). Status of an aircrew who flies the unit aircraft in support duties. An MS pilot requires further training prior to entry into combat.

Search and Rescue (SAR). Locating and recovering downed aircrews in time of war.

Sortie. One flight from take-off to final landing.

Standardization/Evaluation Flight Examiner (SEFE). An IP who is designated to perform aircrew flight evaluations in accordance with the Standardization/Evaluation Program.

Visual Low Level Navigation. A navigation flight flown at or below 1500 feet above the ground on a preplanned route.

Weapons Delivery (WD). Expenditure of munitions against a surface target.

*The definitions in this glossary are extracted from TACM 51-50 and the United States Air Force Dictionary.

APPENDIX B

APPENDIX B

MATHEMATICAL OVERVIEW

To understand the procedures developed in Chapter II, a general knowledge of linear programming techniques is needed. To provide the basic level of information necessary, the basic concepts are reviewed in this appendix. In addition, an introduction is provided to both dynamic and goal programming.

Linear Programming

Linear programming is based on the assumption that a decision maker desires to either maximize something (to make a value as large as possible) or minimize something (to make a value as small as possible). (5:212) The something which is to be maximized or minimized is called the objective function. The objective function is made of two or more variables to which the decision maker can assign values. Variables which can be assigned values by the decision maker and which affect the objective are labeled structural or decision variables. A list of variables with assigned values is called a program or solution.

For the decision maker to develop an optimal program he must identify the relationship existing between the objective and the structural variables. In addition to the objective function, mathematical models are based on the assumption that the decision maker is faced with restrictions on the values which the structural variables can be assigned. These restrictions include limited resources, technical requirements, or other obligations.

Restrictions are included in mathematical models by introducing constraints. A constraint is a relationship that limits the values a structural variable can be assigned. Constraints can be expressed in terms of three propositions. The propositions are (1) equal to, (2) greater than, and (3) less than.

To understand how an optimal solution is obtained, one must know the difference between feasible, infeasible, and optimal programs. A feasible program is one which meets all of the constraints of the mathematical model, whereas an infeasible program violates one or more of the constraints. An optimal program is one which is feasible and either maximizes or minimizes the objective function.

Underlying linear programming is the proposition that the objective function and all the constraints are linear relations and that the structural variables are nonnegative. These considerations can be expressed mathematically as follows:

1. The objective function is expressed as

$$f(z) = a_1x_1 + a_2x_2 + a_3x_3 + \dots + a_nx_n$$

where $a_1, a_2, a_3, \dots, a_n$ are real-valued constants.

2. Each constraint is expressed as

$$b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n = C, \text{ or}$$

$$b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n \geq C, \text{ or}$$

$$b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n \leq C,$$

where $b_1, b_2, b_3, \dots, b_n$ are real-valued constants.

3. The structural variables $x_1, x_2, x_3, \dots, x_n$ are real-valued variables. (2:1)

Simple linear programming models of two variables can be solved manually by using graphical techniques. Linear models which have more than two variables require using nongraphical techniques such as the simplex algorithm. The use of the simplex algorithm technique becomes very tedious as the number of variables increase. Computer manufacturers or company vendors offer computer programs (software) for solving linear programming models. The use of these programs facilitates the solution of linear models and provides the user a number of means for post-optimal solution analysis. (2:144) The ability to perform post-optimal solution analysis allows an evaluation of the effects of changes in any of the constraints which define the problem.

Dynamic Programming

Dynamic programming is a valuable technique when faced with multistage or time related decision processes (processes involving multiple interrelated choices). Multistage decision processes are thought of as being made up of policy choices, stages, states, and objectives. (5:Ch 10)

Policy Choice. A policy choice is a choice (decision) made at some point in a multistage decision process. Usually a policy choice is needed at each of the stages.

Stage. A stage is a set of feasible choices occurring at some point in a multistage decision process.

State. A state is a condition that influences a policy choice at a decision stage.

Objective. An objective is the goal to be attained by the policy choice selected at each stage of the decision process.

In general, dynamic programming may be useful in instances where linear programming models are not feasible. Dynamic algorithms can be developed and computerized for use in solving complex problems with a great number of variables. While this technique is beneficial in solving multistage decision processes, it is by no means a panacea for solving all very large problems. If there are too many state variables at each stage, the amount of computer memory required for storage becomes excessive. The end result is that even very large computers may be unable to accommodate the memory needs of some dynamic programming algorithms.

Goal Programming

Goal programming is gaining in popularity as a technique for solution of problems with competing objectives. It is a relatively recent method which takes into account trade-offs between possible goals or objectives for the decision maker. It is a modification of linear programming which takes advantage of the slack variables to free the decision maker from a one dimensional objective function.* It accomplishes this task by using the slack variables to minimize the deviations between goals that are set within the system of constraints for the problem.

The goals or objectives for the problem are stated and arranged in order of their priority. The algorithm used for the solution process successively seeks the achievement of these goals in priority, where the higher goals become constraints which must not be violated.

*A slack is a variable used to show how much of a given resource was not used in a solution.

Therefore, higher goals are satisfied at the expense of the lower priority goals. This approach will let the decision maker meet as many of his needs as is feasible under the conditions which prevail for the problem.

APPENDIX C

APPENDIX C

VARIABLE LISTING

To read Table 13, read down column one, labeled pilot, to the pilot number desired. Then to determine the variable designation for a specific type sortie move to the right along the same row to where it intersects with the desired column. For example, the variable representing the number of weapons delivery sorties flown by pilot 10 (P10) would be X1001.

TABLE 13

Variables

PILOT	WD (01)	SAT (02)	MAV (03)	ACBT (04)	SAR (05)	NIGHT (06)	COLS (07)
P1	X0101	X0102	X0103	X0104	X0105	X0106	X0107
P2	X0201	X0202	X0203	X0204	X0205	X0206	X0207
P3	X0301	X0302	X0303	X0304	X0305	X0306	X0307
P4	X0401	X0402	X0403	X0404	X0405	X0406	X0407
P5	X0501	X0502	X0503	X0504	X0505	X0506	X0507
P6	X0601	X0602	X0603	X0604	X0605	X0606	X0607
P7	X0701	X0702	X0703	X0704	X0705	X0706	X0707
P8	X0801	X0802	X0803	X0804	X0805	X0806	X0807
P9	X0901	X0902	X0903	X0904	X0905	X0906	X0907
P10	X1001	X1002	X1003	X1004	X1005	X1006	X1007
P11	X1101	X1102	X1103	X1104	X1105	X1106	X1107
P12	X1201	X1202	X1203	X1204	X1205	X1206	X1207
P13	X1301	X1302	X1303	X1304	X1305	X1306	X1307
P14	X1401	X1402	X1403	X1404	X1405	X1406	X1407
P15	X1501	X1502	X1503	X1504	X1505	X1506	X1507
P16	X1601	X1602	X1603	X1604	X1605	X1606	X1607
P17	X1701	X1702	X1703	X1704	X1705	X1706	X1707
P18	X1801	X1802	X1803	X1804	X1805	X1806	X1807
P19	X1901	X1902	X1903	X1904	X1905	X1906	X1907
P20	X2001	X2002	X2003	X2004	X2005	X2006	X2007
P21	X2101	X2102	X2103	X2104	X2105	X2106	X2107

TABLE 13 (Continued)

PILOT	WD (01)	SAT (02)	MAV (03)	ACBT (04)	SAR (05)	NIGHT (06)	COLS (07)
P22	X2201	X2202	X2203	X2204	X2205	X2206	X2207
P23	X2301	X2302	X2303	X2304	X2305	X2306	X2307
P24	X2401	X2402	X2403	X2404	X2405	X2406	X2407
P25	X2501	X2502	X2503	X2504	X2505	X2506	X2507
P26	X2601	X2602	X2603	X2604	X2605	X2606	X2607
P27	X2701	X2702	X2703	X2704	X2705	X2706	X2707
P28	X2801	X2802	X2803	X2804	X2805	X2806	X2807
P29	X2901	X2902	X2903	X2904	X2905	X2906	X2907
P30	X3001	X3002	X3003	X3004	X3005	X3006	X3007
P31	X3101	X3102	X3103	X3104	X3105	X3106	X3107
P32	X3201	X3202	X3203	X3204	X3205	X3206	X3207
P33	X3301	X3302	X3303	X3304	X3305	X3306	X3307
P34	X3401	X3402	X3403	X3404	X3405	X3406	X3407
P35	X3501	X3502	X3503	X3504	X3505	X3506	X3507
P36	X3601	X3602	X3603	X3604	X3605	X3606	X3607
P37	X3701	X3702	X3703	X3704	X3705	X3706	X3707

APPENDIX D

APPENDIX D

FORTRAN COMPUTER ASSISTED SCHEDULING PROGRAM

This appendix contains the program developed to generate the required input for the CDC APEX III LP software package. Although it is written in FORTRAN there is no reason it could not be converted to COBOL or another programming language.

```

      PROGRAM FILLP(INPUT,OUTPUT,TAPE1)
C
C  GENERATE ON TAPE1 INPUT DATA SUITABLE FOR APEX LP PACKAGE
C  FOR PILOT TRAINING FLIGHT ASSIGNMENT PROBLEM
C
C  P1 HOLDS THE INPUT CATEGORY DATA FOR EACH PILOT
C  P2 HOLDS RANKING DATA FOR EACH PILOT IN 5 SORTIE TYPES
C  P3 HOLDS TOTAL AND SORTIE TYPE MAX/MIN FOR EACH PILOT
C  RNKRNK HOLDS PILOT RANKING IN RANK ORDER. THAT IS IF PILOT
C  NUMBER X IS RANKED FIRST FOR FLIGHT 1, THEN RNKRNK(1,X)=1.
C  CUTPER HOLDS CUTPOINT PERCENTAGES FOR SETTING VARIABLE MINS
C  CURRENT VALUES WILL BREAK INTO 10,20,40,20,10 % BRACKETS
C  CUTPT HOLDS CUTPOINTS BASED ON CUTPER AND NUMBER OF PILOTS
C  TABLE CONTAINS 16 VALUES FOR EACH PILOT CATEGORY ENTRY (CURRENTLY 21)
C  VALUES ARE MAX/MIN FOR TOTAL,NO,SAT,NAV,ACFT,SAR,NIGHT,CDLS
C  MIN IS NEGATIVE WHERE MIN VALUE MAY VARY PER PILOT'S RANKING
C  FIXED SET TRUE IF MIN VALUES FOR AN ENTRY DO NOT VARY
C  MAXFLT HOLDS MAX ALLOWED TOTAL PER SORTIE TYPE
C  RESPNS IS WORKING AREA FOR INPUT DATA. MOVED TO P1 AND P2
C
      IMPLICIT INTEGER (A-Z)
      DIMENSION P1(50,7),P2(50,5),P3(50,10)
      DIMENSION RNKRNK(50,5)
      REAL CUTPER(4)
      DIMENSION CUTPT(4)
      DIMENSION TABLE(16,21)
      LOGICAL FIXED(21)
      DIMENSION RESPNS(16),RANK(5),MAXFLT(7)
      EQUIVALENCE (RESPNS(1),RANK(1),(RESPNS(2),TNGCAT),
C  X (RESPNS(3),POSTCT),(RESPNS(4),MONTHS),
C  X (RESPNS(5),CATGRY),(RESPNS(6),STATUS),
C  X (RESPNS(7),IP ),(RESPNS(8),CAPEX ),
C  X (RESPNS(9),GCC ),(RESPNS(10),RANK(1))
C
C  CURRENTLY SET UP FOR AT MOST 50 PILOTS AND 21 CATEGORIES
C  APPROPRIATE ARRAY SIZES AND FOLLOWING DATA STATEMENT SHOULD
C  BE CHANGED TO CHANGE THESE VALUES.
      DATA MAXFLT, NENTRY /50,21/
C
C  FOLLOWING DATA STATEMENT SETS CUTPOINT PERCENTAGES
      DATA CUTPER /.10,.30,.70,.40/

```

C FOLLOWING SET UP THE MAX/MIN VALUES FOR VARIOUS PILOT CATEGORIES

DATA ((TABLE(J,K),J=1,16),K=1,10) /

1 55. 46. 4. -4. 7. -3. 7. -2. 5. -1. 10. 5. 20. 15.
 2 72. 56. 10. -7. 12. -7. 7. -3. 7. -2. 7. -3. 10. 5. 21. 16.
 3 41. 75. 11. -6. 12. -5. 7. -5. 7. -2. 7. -3. 10. 5. 22. 17.
 4 42. 33. 5. -4. 9. -5. 7. -3. 7. -2. 5. -1. 5. 2. 4. 5.
 5 56. 50. 10. -6. 12. -7. 7. -3. 5. -2. 7. -3. 7. 5. 10. 5.
 6 65. 59. 11. -5. 12. -5. 7. -3. 7. -2. 7. -3. 10. 5. 11. 9.
 7 39. 30. 7. 2. 10. 2. 5. 2. 5. 2. 5. 2. 5. 2. 6.
 8 50. 40. 7. -5. 7. -5. 7. -3. 5. -0. 5. -2. 5. 2. 10. 5.
 9 51. 50. 12. -5. 12. -5. 5. -4. 5. -2. 5. -4. 5. 2. 11. 10.
 1 75. 59. 12. -7. 13. -5. 10. -7. 10. -4. 11. -7. 11. 5. 12. 10 /

DATA ((TABLE(J,K),J=1,16),K=1,20) /

1 59. 49. 7. -5. 7. -5. 7. -3. 7. -0. 5. -2. 5. 2. 25. 14.
 2 70. 59. 12. -6. 12. -3. 8. -4. 5. -2. 7. -4. 5. 2. 25. 13.
 3 89. 77. 12. -7. 13. -8. 10. -3. 7. -4. 11. -7. 11. 5. 25. 13.
 4 50. 36. 13. -6. 12. -3. 5. -2. 5. -0. 5. -2. 5. 2. 10. 4.
 5 71. 59. 10. -5. 13. -5. 10. -3. 7. -4. 5. -4. 5. 5. 12. 6.
 6 97. 44. 16. -12. 18. -13. 12. -3. 12. -5. 10. -5. 15. 5. 13. 4.
 7 39. 30. 7. 2. 10. 2. 5. 2. 5. 2. 5. 2. 5. 2. 6.
 8 49. 50. 17. 11. 13. 10. 5. 5. 5. 5. 5. 3. 2. 14. 8.
 9 66. 50. 15. 10. 12. 9. 7. 5. 7. 5. 5. 3. 3. 2. 13. 5.
 1 52. 60. 15. 9. 10. 7. 5. 5. 5. 3. 5. 5. 3. 2. 10. 10 /

DATA ((TABLE(J,K),J=1,16),K=1,21) /

1 57. 45. 13. 10. 7. 5. 5. 5. 5. 5. 5. 3. 4. 2. 15. 12 /

C

KEYS TO TABLE ENTRIES IN FOLLOWING LAYOUT

C

C C

C TABLE TNG NEXT MONTHS PILOT PILOT GCC

C ENTRY CTGRY STATUS TO COMM CTGRY STATUS IP EXPEP LEVEL

C C

C	1	CT			ST-FF	44	YES		A
C	2	CT			ST-FF	42	YES		B
C	3	CT			ST-FF	42	YES		C
C	4	CT			ST-FF	42	NO		A
C	5	CT			ST-FF	42	NO		B
C	6	CT			ST-FF	42	NO		C
C	7	CT			ST-FF	45			
C	8	CT			PRIM		YES	EAP	A
C	9	CT			PRIM		YES	EAP	B
C	10	CT			PRIM		YES	EAP	C
C	11	CT			PRIM		NO	EAP	A
C	12	CT			PRIM		NO	EAP	B
C	13	CT			PRIM		NO	EAP	C
C	14	CT			PRIM			INEXP	A
C	15	CT			PRIM			INEXP	B
C	16	CT			PRIM			INEXP	C
C	17	IOT/MGT	45						
C	18	IOT/MGT	44	1					
C	19	IOT/MGT	42	2					
C	20	IOT/MGT	44	3					
C	21	IOT/MGT	44	4					

C C

C

```

C      CALL CONNED(5LINPUT)
C      CALL CONNED(6LOUTPUT)
C      DETERMINE WHICH ENTRIES WILL HAVE FIXED MINIMUMS
C
C      DO 50 J=1,NENTRY
C      DO 10 K=4,12,2
C      IF (TABLE(K,J).LE.0) GO TO 20
10     CONTINUE
C      FIXED(J)=.TRUE.
C      GO TO 50
20     FIXED(J)=.FALSE.
50     CONTINUE
C
C      HEAD TOTAL NUMBER PILOTS. MAKE SURE ITS UNDER MAX SPACE.
C
C      PRINT 1001
C      READ *.TOTPLT
C      IF (TOTPLT.LE.MAXPLT) GO TO 70
C      PRINT 2001.MAXPLT
C      STOP
C
C      SET UP CUTPOINTS TO BE USED FOR VARIABLE MINS
C
C      DO 80 J=1,4
70     CUTPT(J)=CUTPER(J)*FLOAT(TOTPLT)*0.5
80     CONTINUE
C
C      HEAD OVERALL MAX FLIGHTS BY TYPE
C
C      PRINT 1002
C      READ *.MAXFLT
C
C      START INPUT FOR EACH PILOT. FIRST CLEAR OUT RESPONSE SPACE.
C
C      DO 101 J=1,4
100     RESPNS(J)=0
101     CONTINUE
C
C      PILOT NUMBER. NOT OVER TOTAL AND NOT ALREADY USED.
C      PILOT NUMBER 999 FLAGS END OF INPUT
C
103     PRINT 1003
C      READ *.PNMNR
C      IF (PNMNR.EQ.999) GO TO 300
C      IF (PNMNR.LE.TOTPLT) GO TO 10301
C      PRINT 2002.TOTPLT
C      GO TO 103
10301 IF (PI(PNMNR-1).EQ.0) GO TO 104
C      PRINT 2003
C      GO TO 103
C
C      TRAINING CATEGORY--1=CT,2=QT/MQT

```

```

104  PRINT 1004
      READ *.TNGCAT
      IF (TNGCAT.EQ.1 .OR. TNGCAT.EQ.2) GO TO 10401
      PRINT 2000
      GO TO 104
C JUMP FOR CT. STAY HERE FOR 1JT/MQ1
10401 IF (TNGCAT.EQ.1) GO TO 107
C
C HAVE 1JT/MQ1. GET CATEGORY AFTER TNG--1=MR.2=MS
C
105  PRINT 1005
      READ *.POSTCT
      IF (POSTCT.EQ.1 .OR. POSTCT.EQ.2) GO TO 10501
      PRINT 2000
      GO TO 105
C
C GET MONTHS FOR MR.
C
10501 IF (POSTCT.EQ.2) GO TO 112
106  PRINT 1006
      READ *.MONTHS
      IF (MONTHS.LE.0 .AND. MONTHS.LE.-1) GO TO 112
      PRINT 2000
      GO TO 106
C
C HAVE TNG CATEGORY CT. GET PILOT CATEGORY--1=PRIMARY.2=STAFF
C
107  PRINT 1007
      READ *.CATGRY
      IF (CATGRY.EQ.1 .OR. CATGRY.EQ.2) GO TO 10701
      PRINT 2000
      GO TO 107
C
C FOR PRIMARY STAY AND GET EXPERIENCE--1=EXP.2=INEXP
C
10701 IF (CATGRY.EQ.2) GO TO 109
108  PRINT 1008
      READ *.EXPER
      IF (EXPER.EQ.1 .OR. EXPER.EQ.2) GO TO 10801
      PRINT 2000
      GO TO 108
C PICK UP IP STATE FOR EXPERIENCED.
10801 IF (EXPER.EQ.1) GO TO 110
      GO TO 111
C
C HAVE A STAFF PILOT. DETERMINE STATUS--MR=1. MS=2
C
109  PRINT 1009
      READ *.STATUS
      IF (STATUS.EQ.1 .OR. STATUS.EQ.2) GO TO 10901
      PRINT 2000
      GO TO 109
C SKIP TO RANKS IF MS.
10901 IF (STATUS.EQ.2) GO TO 112

```

```

C IS PILOT IP?--1=YES.2=NO
C
110 PRINT 1010
    READ *.IP
    IF (IP.EQ.1 .OR. IP.EQ.2) GO TO 111
    PRINT 2000
    GO TO 110
C
C GCC LEVEL--1=A.2=M.3=C
C
111 PRINT 1011
    READ *.GCC
    IF (GCC.GT.0 .AND. GCC.LE.3) GO TO 112
    PRINT 2000
    GO TO 111
C
C NOW GET THIS PILOTS RANKINGS BY FLIGHT TYPE
C
112 PRINT 1012
    READ *.RANK
C CHANK INSURES LEGAL RANKS. SAVES THEM IN HRANK.
C WILL TAKE ALTERNATE RETURN IF PROBLEMS DETECTED.
    CALL CHRANK(PNMNR.TOTPLT.RANK.HRANK.P2).RETURNS(112)
C
C DETERMINE WHICH TABLE ENTRY TO USE
C NOTE THAT THIS LOGIC DEPENDS ON UNUSED SELECTION ITEMS
C BEING ZERO TO WORK PROPERLY.
C
    ENTRY=0
    IF (TNGCAT.NE.1) GO TO 150
    IF (CATGRY.EQ.1) ENTRY=7
    IF (STATUS.EQ.2) ENTRY=7
    IF (IP.EQ.2) ENTRY=ENTRY+3
    IF (EXPER.EQ.2) ENTRY=ENTRY+6
    ENTRY=ENTRY+GCC
    GO TO 200
150 ENTRY=17-MONTHS
C
C SAVE THIS PILOT'S DATA AND GET THE NEXT ENTRY
C
200 P1(PNMNR.1)=ENTRY
    DO 210 J=2.9
210 P1(PNMNR.J)=RESPNS(J)
    DO 220 J=1.5
220 P2(PNMNR.J)=RANK(J)
    GO TO 100
C
C ALL DATA HAS BEEN INPUT. NOW SET UP REQUIRED VALUES
C
300 DO 400 PILOT=1.TOTPLT
    ENTRY=P1(PILOT.1)
    DO 310 J=1.15
310 P3(PILOT.J)=TABLE(J,ENTRY)

```

```

C IF MINS CANT VARY THAT IS ALL THAT IS NEEDED.
C
C   IF (FIXED(ENTRY)) GO TO 400
C
C MINS CAN VARY...FIRST GET THIS PILOT'S RANKING
C
C   DO 320 J=1,5
320  RANK(J)=P2(PILOT,J)
C
C NOW FOR FIRST FIVE SORTIE TYPES PICK UP THE BASE MIN
C (WHICH IS A NEGATIVE) AND DECIDE HOW MUCH TO BUMP IT
C BASED ON WHERE THE RANKING HITS THE CUTOPTS.
C
C   DO 350 K=1,5
C   POINT=2*(K-1)
C   BASE=1ABS(P3(PILOT,POINT))
C   DO 330 J=1,4
C   IF (RANK(K).LE.CUTPT(J)) GO TO 335
330  CONTINUE
C   J=5
335  BUMP=J-1
C   P3(PILOT,POINT)=BASE+BUMP
350  CONTINUE
400  CONTINUE
C
C RERANK WILL TOSS OUT INFEASIBLE RANKINGS AND CLEAN UP THE
C RANKING ARRAYS AS NEEDED.
C
C   CALL RERANK(TOTPLT,P2,NNRANK,P3)
C
C CARDS GENERATES THE APEX INPUT ON TAPE1
C
C   CALL CARDS(TOTPLT,MAXFLT,P3,P2,NNRANK)
C
C STOP
C
1001  FORMAT(" TOTAL NUMBER OF PILOTS ?")
1002  FORMAT(" MAX NUMBER OF NO.SAT,NAV,AC-T,SEA,NIGHT,COLS SORTIES",
1 /," ?")
1003  FORMAT(" PILOT NUMBER--(999 TO STOP) ?")
1004  FORMAT(" TRAINING CATEGORY--CT=1,1,1/MUT=2 ?")
1005  FORMAT(" CATEGORY AFTER 1CT/MUT--MM=1,MS=2 ?")
1006  FORMAT(" MONTHS TO COMPLETE 1CT/MUT--1,2,3 OR 4 ?")
1007  FORMAT(" PILOT CATEGORY--P=1,MY=1,STAFF=2 ?")
1008  FORMAT(" PILOT STATUS--MM=1,MS=2 ?")
1009  FORMAT(" IS PILOT AN IP--YES=1,NO=2 ?")
1010  FORMAT(" EXPERIENCED=1,INEXPERIENCED=2 ?")
1011  FORMAT(" GCC LEVEL--A=1,B=2,C=3 ?")
1012  FORMAT(" RANKING FOR NO.SAT,NAV,AC-T,SEA SORTIES"/," ?")
C
2000  FORMAT(" ILLEGAL ENTRY--TRY AGAIN")
2001  FORMAT(" MAX PILOTS ALLOWED IS"/,"(4) MUST CHANGE PROGRAM")
2002  FORMAT(" PILOT NUMBER CAN NOT BE GREATER THAN TOTAL OF"/,"(4)
2003  FORMAT(" DATA FOR THIS PILOT NUMBER ALREADY ENTERED")
C
END

```

```

SUBROUTINE REWANK(TOT, RANK, RANK2, MAX)
C
C WHERE PILOT PA IS RANKED "N" AND PILOT PB IS RANKED "M+1". WE
C DESIRE THE CONSTRAINT THAT PA FLIGHTS BE LESS OR EQUAL PB FLIGHTS.
C THIS IS INFEASIBLE IF PB'S MAX IS LESS THAN PA'S MIN.
C REWANK CHECKS FOR INFEASIBILITIES OF THIS NATURE AND, WHEN FOUND,
C REMOVES PB FROM THE RANKING SCHEME.
C
C IMPLICIT INTEGER (A-Z)
C DIMENSION RANK(50:5), RANK2(50:5)
C DIMENSION MAX(50:10)
C
C DO 10 J=1:5
C DO 10 K=1:TOT
C PLACE=RANK(K,J)
C10 RANK2(PLACE,J)=K
C
C LOOP 30 FIVE TIMES FOR THE FIVE SORTIE TYPES TO BE CHECKED.
C MAXP AND MINP POINT TO MAX AND MIN ENTRIES FOR THE SORTIE TYPE.
C START WITH THE PILOT RANKED FIRST AS PA AND PILOT RANKED SECOND
C AS PB AND MAKE THE CHECK. IF FEASIBLE, THE SECOND PILOT BECOMES
C PA AND THIRD PILOT BECOMES PB AND SO ON TILL ALL ARE CHECKED.
C IF INFEASIBLE, PB IS DROPPED OUT (GIVEN A ZERO RANK), THE NEXT
C RANKED PILOT IS PICKED UP AS PB AND THE CHECK MADE AGAIN.
C
C DO 30 J=1:5
C MAXP=2*J+1
C MINP=MAXP+1
C PA=1
C PB=1
C20 RB=PB-1
C IF(RB.GT.TOT) GO TO 30
C PA=RANK2(RA,J)
C PB=RANK2(RB,J)
C .LT. CHECK WOULD SUFFICE TO FIND INFEASIBILITIES
C AM USING .LE. TO CUT DOWN ON NUMBER OF CONSTRAINTS
C IF(MAX(PB,MAXP).LE.MAX(PA,MINP)) GO TO 25
C RA=PB
C GO TO 20
C25 RANK2(RB,J)=0
C RANK(PB,J)=0
C GO TO 20
C30 CONTINUE
C
C NOW MUST CLEAN UP RANK ARRAY. SUPPOSE PILOT RANKED 3 HAS BEEN
C DROPPED ABOVE. THAT MEANS PILOTS RANKED 4,5,6, ETC. NOW SHOULD
C BE RANKED 3,4,5, ETC. LOOP 50 ACCOMPLISHES THIS.
C
C DO 50 J=1:5
C RANK=1
C K=1
C40 PA=RANK2(RA,J)
C IF(PA.LE.0) GO TO 45
C RANK(PA,J)=RANK

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```

      RANK=RANK+1
45    RANK=1
      IF (MAXLE.TOT) GO TO 40
50    CONTINUE
C
C  ALSO MUST CLEAN UP THE PILOT BY RANKS ARRAY. IF PILOTS WERE
C  DROPPED ABOVE THIS ARRAY NOW HAS ZERO ENTRIES. MOVE ALL NON-ZERO
C  ENTRIES TO FRONT OF THE ARRAY AND ZERO FILL AT END.
C
      DO 40 J=1,5
        IN=1
        OUT=1
70      IF (RANK2(IN,J).EQ.0) GO TO 75
        RANK2(OUT,J)=RANK2(IN,J)
        OUT=OUT+1
75      IN=IN+1
        IF (IN.LE.TOT) GO TO 70
        IF (OUT.GT.TOT) GO TO 40
        DO 78 K=OUT,TOT
78      RANK2(K,J)=0
50    CONTINUE
C
      RETURN
      END
      SUBROUTINE CARDS(NPMT,MAXFLT,MAX,RANK,RANK2)
C
C  GENERATE APEX INPUT DATA
C
      IMPLICIT INTEGER(A-Z)
      DIMENSION RANK(50,5),RANK2(50,5)
      DIMENSION NAMES(7), MAXFLT(7)
      DIMENSION MAX(50,15)
C
      DATA NTP /7/
      DATA NAMES /2=WD,JMSAT,3=MAV,4=ACBT,5=MSAR,6=NVNIGHT,7=MCOLS /
C
C  NAME HEADER AND ROWS SECTION
C
      WRITE(1,2001)
2001  FORMAT("NAME",T15,"PANNELL",T7,"ROWS")
C  ONE ROW FOR EACH FLIGHT TYPE TOTAL
      DO 100 K=1,NTP
100    WRITE(1,2002) NAMES(K)
2002  FORMAT(5H L T,AS)
C  OVERALL TOTAL IS LINEAR COMBINATION OF THE FLIGHT TYPE TOTALS
      DO 110 K=1,NTP*2
        IF (K.EQ.NTP) GO TO 111
        WRITE(1,2003) NAMES(K),NAMES(K+1)
        GO TO 110
111    WRITE(1,2004) NAMES(K)
110    CONTINUE
2003  FORMAT(" ON TOTALS",T15,"T",A5,F25,"1",T40,"T",A5,F50,"1.")
2004  FORMAT(" ON TOTALS",T15,"T",A5,F25,"1.")
C  ONE ROW FOR EACH PILOT TOTAL

```

```

      DO 120 J=1,NPLT
120  WRITE(1,2005) J
2005  FORMAT(" L ",I2.2)
C
C  CONSTRAINT ROWS BASED ON PILOT RANKING FOR EACH FLIGHT TYPE
C
      DO 150 K=1,5
      DO 130 J=1,NPLT
      P1=RANK2(J,K)
      P2=RANK2(J+1,K)
      IF(P2.LE.J) GO TO 150
130  WRITE(1,2101) P1,P2,NAMES(K)
150  CONTINUE
2101  FORMAT(5H L C,I2.2,45)
C
C  COLUMNS SECTION
C
      WRITE(1,2006)
2006  FORMAT("COLUMNS")
C  ONE COLUMN FOR EACH PILOT/FLIGHT TYPE COMBINATION
      DO 250 J=1,NPLT
      DO 240 K=1,NTP
C  ENTER-S INTO FLIGHT TYPE AND PILOT TYPE TOTALS
      WRITE(1,2007) J,NAMES(K),NAMES(K),J
2007  FORMAT(T5,"P",I2.2,45,T15,"T",45,T25,"1.")
      * T40,"P",I2.2,T50,"1.")
C  ENTER INTO RANKING CONSTRAINT. FIRST FIVE FLIGHT TYPES
      IF(K.GT.5) GO TO 240
      CUMPOS=RANK(J,K)
      IF(CUMPOS.EQ.0) GO TO 240
      PREV=RANK2(CUMPOS-1,K)
      NEXT=RANK2(CUMPOS+1,K)
      IF(CUMPOS.EQ.1) PREV=0
      IF(CUMPOS.GE.NPLT) NEXT=0
      IF(PREV.EQ.0) GO TO 210
      WRITE(1,2107) J,NAMES(K),PREV,J,NAMES(K)
2107  FORMAT(T5,"P",I2.2,45,T15,"C",2,I2.2,45,T25,"-1.")
210  IF(NEXT.EQ.0) GO TO 240
      WRITE(1,2108) J,NAMES(K),J,NEXT,NAMES(K)
2108  FORMAT(T5,"P",I2.2,45,T15,"C",2,I2.2,45,T25,"1.")
240  CONTINUE
250  CONTINUE
C
C  RIGHT HAND SIDE SECTION
C
      WRITE(1,2008)
2008  FORMAT("RHS")
C  MAX FOR EACH FLIGHT TYPE TOTAL
      DO 300 K=1,NTP
      WRITE(1,2009) NAMES(K),MAXFLT(K)
2009  FORMAT(T5,"RHS",T15,"T",45,T25,13)
C  MAX FOR EACH PILOT TOTAL
      DO 310 J=1,NPLT
      WRITE(1,2010) J,MAX(J,1)
2010  FORMAT(T5,"RHS",T15,"P",I2.2,T25,13)

```

```

C RANGES SECTION
C USING RANGES TO SET MIN CONSTRAINT ON PILOT TOTALS. MAX
C WAS SET AT RIGHT HAND SIDE.
C
C WRITE(1,2011)
2011 FORMAT("RANGES")
DO 400 J=1,NPLI
  R=MAX(J,1)-MAX(J,2)
  WRITE(1,2012) J,R
400 CONTINUE
2012 FORMAT(15,"RANGES",T15,"",I2.2,T25.13)
C
C BOUNDS SECTION
C SET UPPER AND LOWER INTEGER BOUNDS FOR EACH PILOT/FLIGHT
C TYPE COMBINATION
C
C WRITE(1,2013)
2013 FORMAT("BOUNDS")
DO 500 J=1,NPLI
  DO 500 K=1,NTP
    WRITE(1,2014) IUP,J,NAMES(K),MAX(J,2)*K-1)
    WRITE(1,2014) ILO,J,NAMES(K),MAX(J,2)*K-2)
500 CONTINUE
2014 FORMAT(A4,"BOUNDS",T15,"",I2.2,A5,T25.13)
C
C DATA IUP,ILO /4M UI /4M LI /
C
C WRITE(1,2015)
2015 FORMAT("ENDDATA")
C
C RETURN
C
C SUBROUTINE CHANK(PILOT,TOTAL,WANK,WANK2,P2),RETURNS(AGAIN)
C IMPLICIT INTEGER(A-Z)
C
C CHECK FOR RANK PROBLEMS
C
C DIMENSION WANK(5),WANK2(50,5),P2(50,5)
C
C RANKS IN LEGAL RANGE?
C
C DO 10 J=1,5
C   IF(WANK(J).LE.0 .OR. WANK(J).GT.TOTAL) GO TO 100
10 CONTINUE
C
C RANK ALREADY ASSIGNED TO ANOTHER PILOT?
C
C DO 20 J=1,5
C   K=WANK(J)
C   IF(WANK2(K,J).NE.0) GO TO 200
20 CONTINUE

```

F/6 5/9

NL

$$2 \times 2$$

END
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C  SAVE IN RANKING ARRAY
C
      DO 30 J=1,5
      K=RANK(J)
30   RANK2(K,J)=PILOT
      RETURN
C
100  PRINT 101,TOTAL
101  FORMAT(" RANKS MUST BE IN RANGE 1 TO # PILOTS =",I3)
      RETURN AGAIN
C
200  PRIOR=RANK2(K,J)
      PRINT 201,PRIOR,(P2(PRIOR,L),L=1,5)
201  FORMAT(" CONFLICT WITH PILOT",I3," RANKS=",S13)
      RETURN AGAIN
      END

```

APPENDIX E

APPENDIX E

FORMATTED INPUT

The computer listing in this appendix is the output of the FORTRAN computer assisted scheduling program generated by the CARDS subroutine. It serves as the input to the CDC APEX III LP software package.

NAME	PANNELL			
ROWS				
L TWO				
L TSAT				
L TMAV				
L TACST				
L TSAW				
L TNIGHT				
L TCOLS				
DN TOTALS	TWO	1.	TSAT	1.
DN TOTALS	TMAV	1.	TACST	1.
DN TOTALS	TSAW	1.	TNIGHT	1.
DN TOTALS	TCOLS	1.		
L P01			L P27	
L P02			L P28	
L P03			L P29	
L P04			L P30	
L P05			L P31	
L P06			L P32	
L P07			L P33	
L P08			L P34	
L P09			L P35	
L P10			L P36	
L P11			L P37	
L P12			L C1410w0	
L P13			L C1604w0	
L P14			L C0932w0	
L P15			L C3211w0	
L P16			L C1114w0	
L P17			L C1902w0	
L P18			L C0235w0	
L P19			L C3517w0	
L P20			L C1720w0	
L P21			L C2024w0	
L P22			L C2415w0	
L P23			L C1525w0	
L P24			L C2529w0	
L P25			L C2925w0	
L P26			L C2604w0	

L C041000
L C101200
L C122500
L C253700
L C2304SAT
L C0914SAT
L C1911SAT
L C1102SAT
L C0224SAT
L C2424SAT
L C2504SAT
L C0420SAT
L C2025SAT
L C2510SAT
L C1012SAT
L C1225SAT
L C2537SAT
L C3715SAT
L C1532SAT
L C3224SAT
L C2414SAT
L C3613MAV
L C1304MAV
L C0914MAV
L C1413MAV
L C1324MAV
L C2432MAV
L C3223MAV
L C2324MAV
L C2420MAV
L C2004MAV
L C0413MAV
L C1537MAV
L C3728MAV
L C2812MAV
L C1226MAV
L C2614MAV
L C1925MAV
L C2511MAV
L C1110MAV
L C1015ACBT
L C1413ACBT
L C1305ACBT
L C0537ACBT
L C3719ACBT
L C1925ACBT
L C2005ACBT
L C0504ACBT
L C0923ACBT
L C2312ACBT
L C1232ACBT
L C3224ACBT
L C2404ACBT
L C0415ACBT
L C1502ACBT
L C0236ACBT
L C3625ACBT
L C2524ACBT
L C2420ACBT
L C2011ACBT
L C1125ACBT
L C2304SAH
L C0905SAH
L C0514SAH
L C1407SAH
L C0718SAH

L C1810SAR					
L C1833SAR					
L C3303SAR					
L C0327SAR					
L C2931SAR					
L C3111SAR					
L C1306SAR					
L C0626SAR					
L C3626SAR					
L C2632SAR					
L C3237SAR					
L C3711SAR					
L C1102SAR					
L C0204SAR					
L C0420SAR					
L C2015SAR					
L C1514SAR					
L C1425SAR					
L C2425SAR					
L C2524SAR					
L C2412SAR					
L C1210SAR					
COLUMNS					
P0140	TWU	1.	P01	1.	
P01SAT	TSAT	1.	P01	1.	
P01NAV	TNAV	1.	P01	1.	
P01ACBT	TACBT	1.	P01	1.	
P01SAR	TSAR	1.	P01	1.	
P01NIGHT	TNIGHT	1.	P01	1.	
P01COLS	TCOLS	1.	P01	1.	
P02WU	TWU	1.	P02	1.	
P02WU	C1402WU	-1.			
P02WU	C0235WU	1.			
P02SAT	TSAT	1.	P02	1.	
P02SAT	C1102SAT	-1.			
P02SAT	C0224SAT	1.			
P02NAV	TNAV	1.	P02	1.	
P02ACBT	TACBT	1.	P02	1.	
P02ACBT	C1502ACBT	-1.			
P02ACBT	C0236ACBT	1.			
P02SAR	TSAR	1.	P02	1.	
P02SAR	C1102SAR	-1.			
P02SAR	C0204SAR	1.			
P02NIGHT	TNIGHT	1.	P02	1.	
P02COLS	TCOLS	1.	P02	1.	
P03WU	TWU	1.	P03	1.	
P03SAT	TSAT	1.	P03	1.	
P03NAV	TNAV	1.	P03	1.	
P03ACBT	TACBT	1.	P03	1.	
P03SAR	TSAR	1.	P03	1.	
P03SAR	C3303SAR	-1.			
P03SAR	C0327SAR	1.			
P03NIGHT	TNIGHT	1.	P03	1.	
P03COLS	TCOLS	1.	P03	1.	
P04WU	TWU	1.	P04	1.	
P04WU	C2504WU	-1.			
P04WU	C0410WU	1.			
P04SAT	TSAT	1.	P04	1.	
P04SAT	C2504SAT	-1.			
P04SAT	C0420SAT	1.			
P04NAV	TNAV	1.	P04	1.	
P04NAV	C2004NAV	-1.			
P04NAV	C0415NAV	1.			
P04ACBT	TACBT	1.	P04	1.	
P04ACBT	C2404ACBT	-1.			
P04ACBT	C0415ACBT	1.			

P04SAR	TSAR	1.	P06	1.
P04SAR	C0204SAR	-1.		
P04SAR	C0420SAR	1.		
P04NIGHT	TNIGHT	1.	P06	1.
P04CULS	TCULS	1.	P06	1.
P05WU	TWU	1.	P05	1.
P05SAT	TSAT	1.	P05	1.
P05MAV	TMAV	1.	P05	1.
P05ACBT	TACBT	1.	P05	1.
P05ACBT	C1J05ACBT	-1.		
P05ACBT	C05J7ACBT	1.		
P05SAR	TSAR	1.	P05	1.
P05SAR	C0505SAR	-1.		
P05SAR	C0514SAR	1.		
P05NIGHT	TNIGHT	1.	P05	1.
P05CULS	TCULS	1.	P05	1.
P06WU	TWU	1.	P06	1.
P06SAT	TSAT	1.	P06	1.
P06MAV	TMAV	1.	P06	1.
P06ACBT	TACBT	1.	P06	1.
P06ACBT	C2506ACBT	-1.		
P06ACBT	C0604ACBT	1.		
P06SAR	TSAR	1.	P06	1.
P06SAR	C1J06SAR	-1.		
P06SAR	C06J6SAR	1.		
P06NIGHT	TNIGHT	1.	P06	1.
P06CULS	TCULS	1.	P06	1.
P07WU	TWU	1.	P07	1.
P07SAT	TSAT	1.	P07	1.
P07MAV	TMAV	1.	P07	1.
P07ACBT	TACBT	1.	P07	1.
P07SAR	TSAR	1.	P07	1.
P07SAR	C1407SAR	-1.		
P07SAR	C0718SAR	1.		
P07NIGHT	TNIGHT	1.	P07	1.
P07CULS	TCULS	1.	P07	1.
P08WU	TWU	1.	P08	1.
P08SAT	TSAT	1.	P08	1.
P08MAV	TMAV	1.	P08	1.
P08ACBT	TACBT	1.	P08	1.
P08SAR	TSAR	1.	P08	1.
P08NIGHT	TNIGHT	1.	P08	1.
P08CULS	TCULS	1.	P08	1.
P09WU	TWU	1.	P09	1.
P09WU	C1509WU	-1.		
P09WU	C09J2WU	1.		
P09SAT	TSAT	1.	P09	1.
P09SAT	C2J09SAT	-1.		
P09SAT	C0913SAT	1.		
P09MAV	TMAV	1.	P09	1.
P09MAV	C1J09MAV	-1.		
P09MAV	C0914MAV	1.		
P09ACBT	TACBT	1.	P09	1.
P09ACBT	C0904ACBT	-1.		
P09ACBT	C0923ACBT	1.		
P09SAR	TSAR	1.	P09	1.
P09SAR	C2J09SAR	-1.		
P09SAR	C0905SAR	1.		
P09NIGHT	TNIGHT	1.	P09	1.
P09CULS	TCULS	1.	P09	1.
P10WU	TWU	1.	P10	1.
P10WU	C0410WU	-1.		
P10WU	C1012WU	1.		
P10SAT	TSAT	1.	P10	1.
P10SAT	C2510SAT	-1.		
P10SAT	C1012SAT	1.		

P10NAV	TNAV	1.		
P10NAV	C1110NAV	-1.	P10	1.
P10ACBT	TACBT	1.		
P10ACBT	C1113ACBT	1.	P10	1.
P10SAR	TSAR	1.		
P10SAR	C1210SAR	-1.	P10	1.
P10NIGHT	TNIGHT	1.	P10	1.
P10CULS	TCULS	1.	P10	1.
P11WU	TWU	1.	P11	1.
P11WU	C3211WU	-1.		
P11WU	C1119WU	1.		
P11SAT	TSAT	1.	P11	1.
P11SAT	C1111SAT	-1.		
P11SAT	C1102SAT	1.		
P11NAV	TNAV	1.	P11	1.
P11NAV	C2511NAV	-1.		
P11NAV	C1110NAV	1.		
P11ACBT	TACBT	1.	P11	1.
P11ACBT	C2011ACBT	-1.		
P11ACBT	C1120ACBT	1.		
P11SAR	TSAR	1.	P11	1.
P11SAR	C3711SAR	-1.		
P11SAR	C1102SAR	1.		
P11NIGHT	TNIGHT	1.	P11	1.
P11CULS	TCULS	1.	P11	1.
P12WU	TWU	1.	P12	1.
P12WU	C1012WU	-1.		
P12WU	C1229WU	1.		
P12SAT	TSAT	1.	P12	1.
P12SAT	C1012SAT	-1.		
P12SAT	C1220SAT	1.		
P12NAV	TNAV	1.	P12	1.
P12NAV	C2412NAV	-1.		
P12NAV	C1229NAV	1.		
P12ACBT	TACBT	1.	P12	1.
P12ACBT	C2312ACBT	-1.		
P12ACBT	C1232ACBT	1.		
P12SAR	TSAR	1.	P12	1.
P12SAR	C2412SAR	-1.		
P12SAR	C1210SAR	1.		
P12NIGHT	TNIGHT	1.	P12	1.
P12CULS	TCULS	1.	P12	1.
P13WU	TWU	1.	P13	1.
P13SAT	TSAT	1.	P13	1.
P13NAV	TNAV	1.	P13	1.
P13NAV	C3013NAV	-1.		
P13NAV	C1309NAV	1.		
P13ACBT	TACBT	1.	P13	1.
P13ACBT	C1013ACBT	-1.		
P13ACBT	C1309ACBT	1.		
P13SAR	TSAR	1.	P13	1.
P13SAR	C3113SAR	-1.		
P13SAR	C1300SAR	1.		
P13NIGHT	TNIGHT	1.	P13	1.
P13CULS	TCULS	1.	P13	1.
P14WU	TWU	1.	P14	1.
P14WU	C1110WU	1.		
P14SAT	TSAT	1.	P14	1.
P14NAV	TNAV	1.	P14	1.
P14NAV	C0714NAV	-1.		
P14NAV	C1113NAV	1.		
P14ACBT	TACBT	1.	P14	1.
P14SAR	TSAR	1.	P14	1.
P14SAR	C0514SAR	-1.		
P14SAR	C1107SAR	1.		
P14NIGHT	TNIGHT	1.	P14	1.

P14CULS	TCULS	1.	P14	1.
P15WU	TWU	1.	P15	1.
P15WU	C2415WU	-1.		
P15WU	C1525WU	1.		
P15SAT	TSAT	1.	P15	1.
P15SAT	C3715SAT	-1.		
P15SAT	C15325SAT	1.		
P15MAV	TMAV	1.	P15	1.
P15MAV	C0415MAV	-1.		
P15MAV	C1537MAV	1.		
P15ACBT	TACBT	1.	P15	1.
P15ACBT	C0415ACBT	-1.		
P15ACBT	C15024ACBT	1.		
P15SAR	TSAR	1.	P15	1.
P15SAR	C2015SAR	-1.		
P15SAR	C1519SAR	1.		
P15NIGHT	TNIGHT	1.	P15	1.
P15CULS	TCULS	1.	P15	1.
P16WU	TWU	1.	P16	1.
P16WU	C1416WU	-1.		
P16WU	C1509WU	1.		
P16SAT	TSAT	1.	P16	1.
P16MAV	TMAV	1.	P16	1.
P16ACBT	TACBT	1.	P16	1.
P16SAR	TSAR	1.	P16	1.
P16SAR	C1510SAR	-1.		
P16SAR	C1533SAR	1.		
P16NIGHT	TNIGHT	1.	P16	1.
P16CULS	TCULS	1.	P16	1.
P17WU	TWU	1.	P17	1.
P17WU	C3517WU	-1.		
P17WU	C1720WU	1.		
P17SAT	TSAT	1.	P17	1.
P17MAV	TMAV	1.	P17	1.
P17ACBT	TACBT	1.	P17	1.
P17SAR	TSAR	1.	P17	1.
P17NIGHT	TNIGHT	1.	P17	1.
P17CULS	TCULS	1.	P17	1.
P18WU	TWU	1.	P18	1.
P18SAT	TSAT	1.	P18	1.
P18SAT	C0418SAT	-1.		
P18SAT	C1511SAT	1.		
P18MAV	TMAV	1.	P18	1.
P18MAV	C1418MAV	-1.		
P18MAV	C1429MAV	1.		
P18ACBT	TACBT	1.	P18	1.
P18ACBT	C1018ACBT	-1.		
P18ACBT	C1413ACBT	1.		
P18SAR	TSAR	1.	P18	1.
P18SAR	C0718SAR	-1.		
P18SAR	C1518SAR	1.		
P18NIGHT	TNIGHT	1.	P18	1.
P18CULS	TCULS	1.	P18	1.
P19WU	TWU	1.	P19	1.
P19WU	C1119WU	-1.		
P19WU	C1402WU	1.		
P19SAT	TSAT	1.	P19	1.
P19SAT	C2419SAT	-1.		
P19MAV	TMAV	1.		
P19MAV	C2519MAV	-1.		
P19MAV	C1425MAV	1.		
P19ACBT	TACBT	1.	P19	1.
P19ACBT	C3719ACBT	-1.		
P19ACBT	C1426ACBT	1.		
P19SAR	TSAR	1.	P19	1.
P19SAR	C1519SAR	-1.		

P14SAR	C1428SAR	1.		
P14NIGHT	TNIGHT	1.	P14	1.
P19CJLS	TCJLS	1.	P14	1.
P20=0	T=0	1.	P20	1.
P20=0	C1720=0	-1.		
P20=0	C2024=0	1.		
P20SAT	TSAT	1.	P20	1.
P20SAT	C0420SAT	-1.		
P20SAT	C2025SAT	1.		
P20MAV	TMAV	1.	P20	1.
P20MAV	C2420MAV	-1.		
P20MAV	C2004MAV	1.		
P20ACBT	TACBT	1.	P20	1.
P20ACBT	C2420ACBT	-1.		
P20ACBT	C2011ACBT	1.		
P20SAR	TSAR	1.	P20	1.
P20SAR	C0420SAR	-1.		
P20SAR	C2015SAR	1.		
P20NIGHT	TNIGHT	1.	P20	1.
P20CJLS	TCJLS	1.	P20	1.
P21=0	T=0	1.	P21	1.
P21SAT	TSAT	1.	P21	1.
P21MAV	TMAV	1.	P21	1.
P21ACBT	TACBT	1.	P21	1.
P21SAR	TSAR	1.	P21	1.
P21NIGHT	TNIGHT	1.	P21	1.
P21CJLS	TCJLS	1.	P21	1.
P22=0	T=0	1.	P22	1.
P22SAT	TSAT	1.	P22	1.
P22MAV	TMAV	1.	P22	1.
P22ACBT	TACBT	1.	P22	1.
P22SAR	TSAR	1.	P22	1.
P22NIGHT	TNIGHT	1.	P22	1.
P22CJLS	TCJLS	1.	P22	1.
P23=0	T=0	1.	P23	1.
P23SAT	TSAT	1.	P23	1.
P23SAT	C2309SAT	1.		
P23MAV	TMAV	1.	P23	1.
P23MAV	C3224MAV	-1.		
P23MAV	C2324MAV	1.		
P23ACBT	TACBT	1.	P23	1.
P23ACBT	C0923ACBT	-1.		
P23ACBT	C2312ACBT	1.		
P23SAR	TSAR	1.	P23	1.
P23SAR	C2309SAR	1.		
P23NIGHT	TNIGHT	1.	P23	1.
P23CJLS	TCJLS	1.	P23	1.
P24=0	T=0	1.	P24	1.
P24=0	C2024=0	-1.		
P24=0	C2415=0	1.		
P24SAT	TSAT	1.	P24	1.
P24SAT	C3224SAT	-1.		
P24SAT	C2415SAT	1.		
P24MAV	TMAV	1.	P24	1.
P24MAV	C2324MAV	-1.		
P24MAV	C2420MAV	1.		
P24ACBT	TACBT	1.	P24	1.
P24ACBT	C2524ACBT	-1.		
P24ACBT	C2420ACBT	1.		
P24SAR	TSAR	1.	P24	1.
P24SAR	C2524SAR	-1.		
P24SAR	C2412SAR	1.		
P24NIGHT	TNIGHT	1.	P24	1.
P24CJLS	TCJLS	1.	P24	1.
P25=0	T=0	1.	P25	1.
P25=0	C1525=0	-1.		

P25WU	C252WU	1.		
P25SAT	TSAT	1.	P25	1.
P25SAT	C2025SAT	-1.		
P25SAT	C2510SAT	1.		
P25MAV	TMAV	1.	P25	1.
P25MAV	C1V25MAV	-1.		
P25MAV	C2511MAV	1.		
P25ACBT	TACBT	1.	P25	1.
P25ACBT	C3625ACBT	-1.		
P25ACBT	C2524ACBT	1.		
P25SAR	TSAR	1.	P25	1.
P25SAR	C2525SAR	-1.		
P25SAR	C2524SAR	1.		
P25NIGHT	TNIGHT	1.	P25	1.
P25COLS	TCOLS	1.	P25	1.
P25WU	TWU	1.	P25	1.
P26WU	C2526WU	-1.		
P26WU	C2504WU	1.		
P26SAT	TSAT	1.	P26	1.
P26SAT	C1226SAT	-1.		
P26SAT	C2537SAT	1.		
P26MAV	TMAV	1.	P26	1.
P26MAV	C1226MAV	-1.		
P26MAV	C2519MAV	1.		
P26ACBT	TACBT	1.	P26	1.
P26ACBT	C1V26ACBT	-1.		
P26ACBT	C2505ACBT	1.		
P26SAR	TSAR	1.	P26	1.
P26SAR	C3626SAR	-1.		
P26SAR	C2532SAR	1.		
P26NIGHT	TNIGHT	1.	P26	1.
P26COLS	TCOLS	1.	P26	1.
P27WU	TWU	1.	P27	1.
P27SAT	TSAT	1.	P27	1.
P27MAV	TMAV	1.	P27	1.
P27ACBT	TACBT	1.	P27	1.
P27SAR	TSAR	1.	P27	1.
P27NIGHT	TNIGHT	1.	P27	1.
P27COLS	TCOLS	1.	P27	1.
P28WU	TWU	1.	P28	1.
P28WU	C1228WU	-1.		
P28WU	C2637WU	1.		
P28SAT	TSAT	1.	P28	1.
P28SAT	C2528SAT	-1.		
P28SAT	C2504SAT	1.		
P28MAV	TMAV	1.	P28	1.
P28MAV	C3728MAV	-1.		
P28MAV	C2612MAV	1.		
P28ACBT	TACBT	1.	P28	1.
P28ACBT	C1128ACBT	-1.		
P28SAR	TSAR	1.	P28	1.
P28SAR	C1V28SAR	-1.		
P28SAR	C2525SAR	1.		
P28NIGHT	TNIGHT	1.	P28	1.
P28COLS	TCOLS	1.	P28	1.
P29WU	TWU	1.	P29	1.
P29WU	C2529WU	-1.		
P29WU	C2525WU	1.		
P29SAT	TSAT	1.	P29	1.
P29SAT	C0229SAT	-1.		
P29SAT	C2528SAT	1.		
P29MAV	TMAV	1.	P29	1.
P29MAV	C1V29MAV	-1.		
P29MAV	C2532MAV	1.		
P29ACBT	TACBT	1.	P29	1.
P29ACBT	C3229ACBT	-1.		

P29ACBT	C290ACBT	1.		
P29SAR	TSAR	1.	P29	1.
P29SAR	C0329SAR	-1.		
P29SAR	C2931SAR	1.		
P29NIGHT	TNIGHT	1.	P29	1.
P29CULS	TCULS	1.	P29	1.
P30WU	TWU	1.	P30	1.
P30SAT	TSAT	1.	P30	1.
P30MAV	TMAV	1.	P30	1.
P30ACBT	TACBT	1.	P30	1.
P30SAR	TSAR	1.	P30	1.
P30NIGHT	TNIGHT	1.	P30	1.
P30CULS	TCULS	1.	P30	1.
P31WU	TWU	1.	P31	1.
P31SAT	TSAT	1.	P31	1.
P31MAV	TMAV	1.	P31	1.
P31ACBT	TACBT	1.	P31	1.
P31SAR	TSAR	1.	P31	1.
P31SAR	C2931SAR	-1.		
P31SAR	C3113SAR	1.		
P31NIGHT	TNIGHT	1.	P31	1.
P31CULS	TCULS	1.	P31	1.
P32WU	TWU	1.	P32	1.
P32WU	C0432WU	-1.		
P32WU	C3211WU	1.		
P32SAT	TSAT	1.	P32	1.
P32SAT	C1532SAT	-1.		
P32SAT	C3223SAT	1.		
P32MAV	TMAV	1.	P32	1.
P32MAV	C2432MAV	-1.		
P32MAV	C3223MAV	1.		
P32ACBT	TACBT	1.	P32	1.
P32ACBT	C1232ACBT	-1.		
P32ACBT	C3229ACBT	1.		
P32SAR	TSAR	1.	P32	1.
P32SAR	C2532SAR	-1.		
P32SAR	C3237SAR	1.		
P32NIGHT	TNIGHT	1.	P32	1.
P32CULS	TCULS	1.	P32	1.
P33WU	TWU	1.	P33	1.
P33SAT	TSAT	1.	P33	1.
P33MAV	TMAV	1.	P33	1.
P33ACBT	TACBT	1.	P33	1.
P33SAR	TSAR	1.	P33	1.
P33SAR	C1533SAR	-1.		
P33SAR	C3303SAR	1.		
P33NIGHT	TNIGHT	1.	P33	1.
P33CULS	TCULS	1.	P33	1.
P34WU	TWU	1.	P34	1.
P34SAT	TSAT	1.	P34	1.
P34MAV	TMAV	1.	P34	1.
P34ACBT	TACBT	1.	P34	1.
P34SAR	TSAR	1.	P34	1.
P34NIGHT	TNIGHT	1.	P34	1.
P34CULS	TCULS	1.	P34	1.
P35WU	TWU	1.	P35	1.
P35WU	C0235WU	-1.		
P35WU	C3517WU	1.		
P35SAT	TSAT	1.	P35	1.
P35MAV	TMAV	1.	P35	1.
P35ACBT	TACBT	1.	P35	1.
P35SAR	TSAR	1.	P35	1.
P35NIGHT	TNIGHT	1.	P35	1.
P35CULS	TCULS	1.	P35	1.
P36WU	TWU	1.	P36	1.
P36SAT	TSAT	1.	P36	1.

P364AV	TMAY	1.	P36	1.
P364AV	C3513MAV	1.	P36	1.
P36ACBT	TACBT	1.	P36	1.
P36ACBT	C0235ACBT	-1.	P36	1.
P36ACBT	C3625ACBT	1.	P36	1.
P36SAR	TSAR	1.	P36	1.
P36SAR	C0630SAR	-1.	P36	1.
P36SAR	C3620SAR	1.	P36	1.
P36NIGHT	TNIGHT	1.	P36	1.
P36COLS	TCOLS	1.	P36	1.
P374U	T4U	1.	P37	1.
P374U	C25374U	-1.	P37	1.
P37SAT	TSAT	1.	P37	1.
P37SAT	C2637SAT	-1.	P37	1.
P37SAT	C3715SAT	1.	P37	1.
P37MAV	TMAY	1.	P37	1.
P37MAV	C1537MAV	-1.	P37	1.
P37MAV	C3725MAV	1.	P37	1.
P37ACBT	TACBT	1.	P37	1.
P37ACBT	C0537ACBT	-1.	P37	1.
P37ACBT	C3719ACBT	1.	P37	1.
P37SAR	TSAR	1.	P37	1.
P37SAR	C3237SAR	-1.	P37	1.
P37SAR	C3711SAR	1.	P37	1.
P37NIGHT	TNIGHT	1.	P37	1.
P37COLS	TCOLS	1.	P37	1.
4MS	T4D	402		
4MS	TSAT	551		
4MS	TMAY	362		
4MS	TACBT	157		
4MS	TSAR	313		
4MS	TNIGHT	-11		
4MS	TCOLS	522		
4MS	P01	39		
4MS	P02	97		
4MS	P03	89		
4MS	P04	97		
4MS	P05	76		
4MS	P06	84		
4MS	P07	84		
4MS	P08	34		
4MS	P09	76		
4MS	P10	47		
4MS	P11	47		
4MS	P12	97		
4MS	P13	81		
4MS	P14	34		
4MS	P15	97		
4MS	P16	81		
4MS	P17	57		
4MS	P18	64		
4MS	P19	47		
4MS	P20	97		
4MS	P21	65		
4MS	P22	57		
4MS	P23	76		
4MS	P24	97		
4MS	P25	47		
4MS	P26	97		
4MS	P27	39		
4MS	P28	47		
4MS	P29	47		
4MS	P30	82		
4MS	P31	89		
4MS	P32	97		

HMS	P33	84	UI	BOUNDUS	P02SAR	10	
HMS	P34	57	LI	BOUNDUS	P02SAR	9	
HMS	P35	66	UI	BOUNDUS	P02NIGHT	13	
HMS	P36	76	LI	BOUNDUS	P02NIGHT	6	
HMS	P37	97	UI	BOUNDUS	P02CULS	13	
RANGES			LI	BOUNDUS	P02CULS	6	
RANGES	P01	4	UI	BOUNDUS	P03WU	12	
RANGES	P02	13	LI	BOUNDUS	P03WU	9	
RANGES	P03	12	UI	BOUNDUS	P03SAT	13	
RANGES	P04	13	LI	BOUNDUS	P03SAT	10	
RANGES	P05	7	UI	BOUNDUS	P03MAV	10	
RANGES	P06	12	LI	BOUNDUS	P03MAV	4	
RANGES	P07	12	UI	BOUNDUS	P03ACBT	6	
RANGES	P08	9	LI	BOUNDUS	P03ACBT	6	
RANGES	P09	7	UI	BOUNDUS	P03SAR	11	
RANGES	P10	13	LI	BOUNDUS	P03SAR	6	
RANGES	P11	13	UI	BOUNDUS	P03NIGHT	11	
RANGES	P12	13	LI	BOUNDUS	P03NIGHT	6	
RANGES	P13	6	UI	BOUNDUS	P03COLS	23	
RANGES	P14	12	LI	BOUNDUS	P03CULS	14	
RANGES	P15	13	UI	BOUNDUS	P04WU	16	
RANGES	P16	6	LI	BOUNDUS	P04WU	14	
RANGES	P17	12	UI	BOUNDUS	P04SAT	16	
RANGES	P18	12	LI	BOUNDUS	P04SAT	15	
RANGES	P19	13	UI	BOUNDUS	P04MAV	12	
RANGES	P20	13	LI	BOUNDUS	P04MAV	10	
RANGES	P21	6	UI	BOUNDUS	P04ACBT	12	
RANGES	P22	12	LI	BOUNDUS	P04ACBT	3	
RANGES	P23	7	UI	BOUNDUS	P04SAR	10	
RANGES	P24	13	LI	BOUNDUS	P04SAR	3	
RANGES	P25	13	UI	BOUNDUS	P04NIGHT	15	
RANGES	P26	13	LI	BOUNDUS	P04NIGHT	6	
RANGES	P27	4	UI	BOUNDUS	P04COLS	13	
RANGES	P28	13	LI	BOUNDUS	P04CULS	3	
RANGES	P29	13	UI	BOUNDUS	P05WU	12	
RANGES	P30	2	LI	BOUNDUS	P05WU	8	
RANGES	P31	12	UI	BOUNDUS	P05SAT	13	
RANGES	P32	13	LI	BOUNDUS	P05SAT	4	
RANGES	P33	12	UI	BOUNDUS	P05MAV	10	
RANGES	P34	12	LI	BOUNDUS	P05MAV	6	
RANGES	P35	16	UI	BOUNDUS	P05ACBT	10	
RANGES	P36	7	LI	BOUNDUS	P05ACBT	4	
RANGES	P37	13	UI	BOUNDUS	P05SAR	11	
BOUNDUS			LI	BOUNDUS	P05SAR	7	
UI	BOUNDUS	P01WU	6	UI	BOUNDUS	P05NIGHT	11
LI	BOUNDUS	P01WU	2	LI	BOUNDUS	P05NIGHT	6
UI	BOUNDUS	P01SAT	10	UI	BOUNDUS	P05COLS	12
LI	BOUNDUS	P01SAT	2	LI	BOUNDUS	P05CULS	10
UI	BOUNDUS	P01MAV	6	UI	BOUNDUS	P06WU	12
LI	BOUNDUS	P01MAV	2	LI	BOUNDUS	P06WU	4
UI	BOUNDUS	P01ACBT	6	UI	BOUNDUS	P06SAT	13
LI	BOUNDUS	P01ACBT	2	LI	BOUNDUS	P06SAT	10
UI	BOUNDUS	P01SAR	3	UI	BOUNDUS	P06MAV	10
LI	BOUNDUS	P01SAR	2	LI	BOUNDUS	P06MAV	3
UI	BOUNDUS	P01NIGHT	6	UI	BOUNDUS	P06ACBT	6
LI	BOUNDUS	P01NIGHT	2	LI	BOUNDUS	P06ACBT	3
UI	BOUNDUS	P01COLS	9	UI	BOUNDUS	P06SAR	11
LI	BOUNDUS	P01COLS	6	LI	BOUNDUS	P06SAR	4
UI	BOUNDUS	P02WU	16	UI	BOUNDUS	P06NIGHT	11
LI	BOUNDUS	P02WU	13	LI	BOUNDUS	P06NIGHT	6
UI	BOUNDUS	P02SAT	18	UI	BOUNDUS	P06COLS	23
LI	BOUNDUS	P02SAT	14	LI	BOUNDUS	P06COLS	14
UI	BOUNDUS	P02MAV	12	UI	BOUNDUS	P07WU	12
LI	BOUNDUS	P02MAV	12	LI	BOUNDUS	P07WU	3
UI	BOUNDUS	P02ACBT	12	UI	BOUNDUS	P07SAT	13
LI	BOUNDUS	P02ACBT	8	LI	BOUNDUS	P07SAT	4

UI	BOUNUS	P07MAV	10	UI	BOUNUS	P12JU	16
LI	BOUNUS	P07MAV	8	LI	BOUNUS	P12WU	15
UI	BOUNUS	P07ACBT	8	UI	BOUNUS	P12SAT	16
LI	BOUNUS	P07ACBT	7	LI	BOUNUS	P12SAT	16
UI	BOUNUS	P07SAR	11	UI	BOUNUS	P12MAV	12
LI	BOUNUS	P07SAR	8	LI	BOUNUS	P12MAV	10
UI	BOUNUS	P07NIGHT	11	UI	BOUNUS	P12ACBT	12
LI	BOUNUS	P07NIGHT	6	LI	BOUNUS	P12ACBT	6
UI	BOUNUS	P07CULS	25	UI	BOUNUS	P12SAW	10
LI	BOUNUS	P07CULS	19	LI	BOUNUS	P12SAW	4
UI	BOUNUS	P08WU	6	UI	BOUNUS	P12NIGHT	15
LI	BOUNUS	P08WU	2	LI	BOUNUS	P12NIGHT	5
UI	BOUNUS	P08SAT	10	UI	BOUNUS	P12CULS	13
LI	BOUNUS	P08SAT	2	LI	BOUNUS	P12CULS	6
UI	BOUNUS	P08MAV	6	UI	BOUNUS	P13WU	11
LI	BOUNUS	P08MAV	2	LI	BOUNUS	P13WU	4
UI	BOUNUS	P08ACBT	6	UI	BOUNUS	P13SAT	12
LI	BOUNUS	P08ACBT	2	LI	BOUNUS	P13SAT	7
UI	BOUNUS	P08SAW	5	UI	BOUNUS	P13MAV	4
LI	BOUNUS	P08SAW	2	LI	BOUNUS	P13MAV	5
UI	BOUNUS	P08NIGHT	5	UI	BOUNUS	P13ACBT	7
LI	BOUNUS	P08NIGHT	2	LI	BOUNUS	P13ACBT	2
UI	BOUNUS	P08CULS	4	UI	BOUNUS	P13SAR	4
LI	BOUNUS	P08CULS	6	LI	BOUNUS	P13SAR	7
UI	BOUNUS	P09WU	12	UI	BOUNUS	P13NIGHT	10
LI	BOUNUS	P09WU	7	LI	BOUNUS	P13NIGHT	5
UI	BOUNUS	P09SAT	13	UI	BOUNUS	P13CULS	22
LI	BOUNUS	P09SAT	8	LI	BOUNUS	P13CULS	17
UI	BOUNUS	P09MAV	10	UI	BOUNUS	P14WU	12
LI	BOUNUS	P09MAV	6	LI	BOUNUS	P14WU	7
UI	BOUNUS	P09ACBT	10	UI	BOUNUS	P14SAT	13
LI	BOUNUS	P09ACBT	5	LI	BOUNUS	P14SAT	4
UI	BOUNUS	P09SAR	11	UI	BOUNUS	P14MAV	10
LI	BOUNUS	P09SAR	7	LI	BOUNUS	P14MAV	6
UI	BOUNUS	P09NIGHT	11	UI	BOUNUS	P14ACBT	6
LI	BOUNUS	P09NIGHT	6	LI	BOUNUS	P14ACBT	7
UI	BOUNUS	P09CULS	12	UI	BOUNUS	P14SAW	11
LI	BOUNUS	P09CULS	10	LI	BOUNUS	P14SAW	7
UI	BOUNUS	P10WU	16	UI	BOUNUS	P14NIGHT	11
LI	BOUNUS	P10WU	14	LI	BOUNUS	P14NIGHT	6
UI	BOUNUS	P10SAT	16	UI	BOUNUS	P14CULS	25
LI	BOUNUS	P10SAT	15	LI	BOUNUS	P14CULS	14
UI	BOUNUS	P10MAV	12	UI	BOUNUS	P15WU	16
LI	BOUNUS	P10MAV	12	LI	BOUNUS	P15WU	14
UI	BOUNUS	P10ACBT	12	UI	BOUNUS	P15SAT	16
LI	BOUNUS	P10ACBT	6	LI	BOUNUS	P15SAT	16
UI	BOUNUS	P10SAR	10	UI	BOUNUS	P15MAV	12
LI	BOUNUS	P10SAR	4	LI	BOUNUS	P15MAV	10
UI	BOUNUS	P10NIGHT	15	UI	BOUNUS	P15ACBT	12
LI	BOUNUS	P10NIGHT	6	LI	BOUNUS	P15ACBT	6
UI	BOUNUS	P10CULS	13	UI	BOUNUS	P15SAW	10
LI	BOUNUS	P10CULS	8	LI	BOUNUS	P15SAW	8
UI	BOUNUS	P11WU	16	UI	BOUNUS	P15NIGHT	15
LI	BOUNUS	P11WU	13	LI	BOUNUS	P15NIGHT	5
UI	BOUNUS	P11SAT	16	UI	BOUNUS	P15CULS	13
LI	BOUNUS	P11SAT	13	LI	BOUNUS	P15CULS	6
UI	BOUNUS	P11MAV	12	UI	BOUNUS	P16WU	11
LI	BOUNUS	P11MAV	11	LI	BOUNUS	P16WU	6
UI	BOUNUS	P11ACBT	12	UI	BOUNUS	P16SAT	12
LI	BOUNUS	P11ACBT	4	LI	BOUNUS	P16SAT	7
UI	BOUNUS	P11SAR	10	UI	BOUNUS	P16MAV	4
LI	BOUNUS	P11SAR	6	LI	BOUNUS	P16MAV	7
UI	BOUNUS	P11NIGHT	15	UI	BOUNUS	P16ACBT	7
LI	BOUNUS	P11NIGHT	6	LI	BOUNUS	P16ACBT	4
UI	BOUNUS	P11CULS	13	UI	BOUNUS	P16SAW	4
LI	BOUNUS	P11CULS	8	LI	BOUNUS	P16SAW	6

UI	BOUNUS	P16NIGHT	10	UI	BOUNUS	P21ACBT	7
LI	BOUNUS	P16NIGHT	5	LI	BOUNUS	P21ACBT	5
UI	BOUNUS	P16CULS	22	UI	BOUNUS	P21SAP	9
LI	BOUNUS	P16CULS	17	LI	BOUNUS	P21SAP	9
UI	BOUNUS	P17WU	13	UI	BOUNUS	P21NIGHT	10
LI	BOUNUS	P17WU	10	LI	BOUNUS	P21NIGHT	5
UI	BOUNUS	P17SAT	7	UI	BOUNUS	P21CULS	11
LI	BOUNUS	P17SAT	4	LI	BOUNUS	P21CULS	9
UI	BOUNUS	P17MAV	5	UI	BOUNUS	P22WU	13
LI	BOUNUS	P17MAV	3	LI	BOUNUS	P22WU	10
UI	BOUNUS	P17ACBT	6	UI	BOUNUS	P22SAT	7
LI	BOUNUS	P17ACBT	5	LI	BOUNUS	P22SAT	4
UI	BOUNUS	P17SAP	5	UI	BOUNUS	P22MAV	5
LI	BOUNUS	P17SAP	3	LI	BOUNUS	P22MAV	3
UI	BOUNUS	P17NIGHT	4	UI	BOUNUS	P22ACBT	6
LI	BOUNUS	P17NIGHT	2	LI	BOUNUS	P22ACBT	6
UI	BOUNUS	P17CULS	18	UI	BOUNUS	P22SAP	6
LI	BOUNUS	P17CULS	12	LI	BOUNUS	P22SAP	3
UI	BOUNUS	P18WU	12	UI	BOUNUS	P22NIGHT	4
LI	BOUNUS	P18WU	10	LI	BOUNUS	P22NIGHT	2
UI	BOUNUS	P18SAT	13	UI	BOUNUS	P22CULS	18
LI	BOUNUS	P18SAT	8	LI	BOUNUS	P22CULS	12
UI	BOUNUS	P18MAV	10	UI	BOUNUS	P23WU	12
LI	BOUNUS	P18MAV	7	LI	BOUNUS	P23WU	8
UI	BOUNUS	P18ACBT	8	UI	BOUNUS	P23SAT	13
LI	BOUNUS	P18ACBT	4	LI	BOUNUS	P23SAT	5
UI	BOUNUS	P18SAP	11	UI	BOUNUS	P23MAV	10
LI	BOUNUS	P18SAP	8	LI	BOUNUS	P23MAV	7
UI	BOUNUS	P18NIGHT	11	UI	BOUNUS	P23ACBT	10
LI	BOUNUS	P18NIGHT	5	LI	BOUNUS	P23ACBT	5
UI	BOUNUS	P18CULS	25	UI	BOUNUS	P23SAP	11
LI	BOUNUS	P18CULS	19	LI	BOUNUS	P23SAP	7
UI	BOUNUS	P19WU	16	UI	BOUNUS	P23NIGHT	11
LI	BOUNUS	P19WU	13	LI	BOUNUS	P23NIGHT	5
UI	BOUNUS	P19SAT	18	UI	BOUNUS	P23CULS	12
LI	BOUNUS	P19SAT	17	LI	BOUNUS	P23CULS	10
UI	BOUNUS	P19MAV	12	UI	BOUNUS	P24WU	16
LI	BOUNUS	P19MAV	11	LI	BOUNUS	P24WU	14
UI	BOUNUS	P19ACBT	12	UI	BOUNUS	P24SAT	18
LI	BOUNUS	P19ACBT	7	LI	BOUNUS	P24SAT	17
UI	BOUNUS	P19SAP	10	UI	BOUNUS	P24MAV	12
LI	BOUNUS	P19SAP	5	LI	BOUNUS	P24MAV	9
UI	BOUNUS	P19NIGHT	15	UI	BOUNUS	P24ACBT	12
LI	BOUNUS	P19NIGHT	5	LI	BOUNUS	P24ACBT	5
UI	BOUNUS	P19CULS	13	UI	BOUNUS	P24SAP	10
LI	BOUNUS	P19CULS	8	LI	BOUNUS	P24SAP	9
UI	BOUNUS	P20WU	16	UI	BOUNUS	P24NIGHT	15
LI	BOUNUS	P20WU	14	LI	BOUNUS	P24NIGHT	5
UI	BOUNUS	P20SAT	18	UI	BOUNUS	P24CULS	13
LI	BOUNUS	P20SAT	15	LI	BOUNUS	P24CULS	5
UI	BOUNUS	P20MAV	12	UI	BOUNUS	P25WU	16
LI	BOUNUS	P20MAV	10	LI	BOUNUS	P25WU	14
UI	BOUNUS	P20ACBT	12	UI	BOUNUS	P25SAT	18
LI	BOUNUS	P20ACBT	9	LI	BOUNUS	P25SAT	15
UI	BOUNUS	P20SAP	10	UI	BOUNUS	P25MAV	12
LI	BOUNUS	P20SAP	8	LI	BOUNUS	P25MAV	11
UI	BOUNUS	P20NIGHT	15	UI	BOUNUS	P25ACBT	12
LI	BOUNUS	P20NIGHT	6	LI	BOUNUS	P25ACBT	5
UI	BOUNUS	P20CULS	13	UI	BOUNUS	P25SAP	10
LI	BOUNUS	P20CULS	8	LI	BOUNUS	P25SAP	8
UI	BOUNUS	P21WU	11	UI	BOUNUS	P25NIGHT	15
LI	BOUNUS	P21WU	10	LI	BOUNUS	P25NIGHT	6
UI	BOUNUS	P21SAT	12	UI	BOUNUS	P25CULS	13
LI	BOUNUS	P21SAT	9	LI	BOUNUS	P25CULS	8
UI	BOUNUS	P21MAV	9	UI	BOUNUS	P25WU	16
LI	BOUNUS	P21MAV	5	LI	BOUNUS	P25WU	14

UI	BOUNUS	P25SAT	18	UI	BOUNUS	P30COLS	10
LI	BOUNUS	P25SAT	10	LI	BOUNUS	P30COLS	10
UI	BOUNUS	P25MAV	12	UI	BOUNUS	P31WU	12
LI	BOUNUS	P25MAV	10	LI	BOUNUS	P31WU	8
UI	BOUNUS	P25ACBT	12	UI	BOUNUS	P31SAT	13
LI	BOUNUS	P25ACBT	7	LI	BOUNUS	P31SAT	9
UI	BOUNUS	P25SAR	10	UI	BOUNUS	P31MAV	10
LI	BOUNUS	P25SAR	8	LI	BOUNUS	P31MAV	9
UI	BOUNUS	P26NIGHT	15	UI	BOUNUS	P31ACBT	8
LI	BOUNUS	P26NIGHT	6	LI	BOUNUS	P31ACBT	0
UI	BOUNUS	P26COLS	13	UI	BOUNUS	P31SAR	11
LI	BOUNUS	P26COLS	8	LI	BOUNUS	P31SAR	8
UI	BOUNUS	P27WU	0	UI	BOUNUS	P31NIGHT	11
LI	BOUNUS	P27WU	2	LI	BOUNUS	P31NIGHT	5
UI	BOUNUS	P27SAT	10	UI	BOUNUS	P31COLS	25
LI	BOUNUS	P27SAT	2	LI	BOUNUS	P31COLS	19
UI	BOUNUS	P27MAV	8	UI	BOUNUS	P32WU	16
LI	BOUNUS	P27MAV	2	LI	BOUNUS	P32WU	12
UI	BOUNUS	P27ACBT	6	UI	BOUNUS	P32SAT	18
LI	BOUNUS	P27ACBT	2	LI	BOUNUS	P32SAT	17
UI	BOUNUS	P27SAR	5	UI	BOUNUS	P32MAV	12
LI	BOUNUS	P27SAR	2	LI	BOUNUS	P32MAV	4
UI	BOUNUS	P27NIGHT	0	UI	BOUNUS	P32ACBT	12
LI	BOUNUS	P27NIGHT	2	LI	BOUNUS	P32ACBT	8
UI	BOUNUS	P27COLS	9	UI	BOUNUS	P32SAR	10
LI	BOUNUS	P27COLS	5	LI	BOUNUS	P32SAR	8
UI	BOUNUS	P28WU	10	UI	BOUNUS	P32NIGHT	15
LI	BOUNUS	P28WU	15	LI	BOUNUS	P32NIGHT	5
UI	BOUNUS	P28SAT	18	UI	BOUNUS	P32COLS	13
LI	BOUNUS	P28SAT	15	LI	BOUNUS	P32COLS	5
UI	BOUNUS	P28MAV	12	UI	BOUNUS	P33WU	12
LI	BOUNUS	P28MAV	10	LI	BOUNUS	P33WU	4
UI	BOUNUS	P28ACBT	12	UI	BOUNUS	P33SAT	13
LI	BOUNUS	P28ACBT	9	LI	BOUNUS	P33SAT	4
UI	BOUNUS	P28SAR	10	UI	BOUNUS	P33MAV	10
LI	BOUNUS	P28SAR	8	LI	BOUNUS	P33MAV	8
UI	BOUNUS	P28NIGHT	15	UI	BOUNUS	P33ACBT	8
LI	BOUNUS	P28NIGHT	6	LI	BOUNUS	P33ACBT	6
UI	BOUNUS	P28COLS	13	UI	BOUNUS	P33SAR	11
LI	BOUNUS	P28COLS	8	LI	BOUNUS	P33SAR	5
UI	BOUNUS	P29WU	10	UI	BOUNUS	P33NIGHT	11
LI	BOUNUS	P29WU	14	LI	BOUNUS	P33NIGHT	0
UI	BOUNUS	P29SAT	18	UI	BOUNUS	P33COLS	25
LI	BOUNUS	P29SAT	14	LI	BOUNUS	P33COLS	14
UI	BOUNUS	P29MAV	12	UI	BOUNUS	P34WU	13
LI	BOUNUS	P29MAV	9	LI	BOUNUS	P34WU	10
UI	BOUNUS	P29ACBT	12	UI	BOUNUS	P34SAT	7
LI	BOUNUS	P29ACBT	5	LI	BOUNUS	P34SAT	4
UI	BOUNUS	P29SAR	10	UI	BOUNUS	P34MAV	5
LI	BOUNUS	P29SAR	7	LI	BOUNUS	P34MAV	3
UI	BOUNUS	P29NIGHT	15	UI	BOUNUS	P34ACBT	0
LI	BOUNUS	P29NIGHT	0	LI	BOUNUS	P34ACBT	5
UI	BOUNUS	P29COLS	13	UI	BOUNUS	P34SAR	6
LI	BOUNUS	P29COLS	8	LI	BOUNUS	P34SAR	3
UI	BOUNUS	P30WU	15	UI	BOUNUS	P34NIGHT	6
LI	BOUNUS	P30WU	4	LI	BOUNUS	P34NIGHT	2
UI	BOUNUS	P30SAT	10	UI	BOUNUS	P34COLS	18
LI	BOUNUS	P30SAT	7	LI	BOUNUS	P34COLS	12
UI	BOUNUS	P30MAV	5	UI	BOUNUS	P35WU	16
LI	BOUNUS	P30MAV	4	LI	BOUNUS	P35WU	10
UI	BOUNUS	P30ACBT	6	UI	BOUNUS	P35SAT	12
LI	BOUNUS	P30ACBT	3	LI	BOUNUS	P35SAT	4
UI	BOUNUS	P30SAR	5	UI	BOUNUS	P35MAV	7
LI	BOUNUS	P30SAR	3	LI	BOUNUS	P35MAV	5
UI	BOUNUS	P30NIGHT	3	UI	BOUNUS	P35ACBT	7
LI	BOUNUS	P30NIGHT	2	LI	BOUNUS	P35ACBT	4

UI	SOUNUS	P35SAW	5
LI	SOUNUS	P35SAW	3
UI	SOUNUS	P35NIGHT	3
LI	SOUNUS	P35NIGHT	2
UI	SOUNUS	P35CULS	13
LI	SOUNUS	P35CULS	4
UI	SOUNUS	P36WD	12
LI	SOUNUS	P36WD	10
UI	SOUNUS	P36SAT	13
LI	SOUNUS	P36SAT	10
UI	SOUNUS	P36MAV	10
LI	SOUNUS	P36MAV	5
UI	SOUNUS	P36ACBT	10
LI	SOUNUS	P36ACBT	5
UI	SOUNUS	P36SAP	11
LI	SOUNUS	P36SAP	4
UI	SOUNUS	P36NIGHT	11
LI	SOUNUS	P36NIGHT	5
UI	SOUNUS	P36CULS	12
LI	SOUNUS	P36CULS	10
UI	SOUNUS	P37WD	10
LI	SOUNUS	P37WD	10
UI	SOUNUS	P37SAT	10
LI	SOUNUS	P37SAT	10
UI	SOUNUS	P37MAV	12
LI	SOUNUS	P37MAV	10
UI	SOUNUS	P37ACBT	12
LI	SOUNUS	P37ACBT	7
UI	SOUNUS	P37SAP	10
LI	SOUNUS	P37SAP	5
UI	SOUNUS	P37NIGHT	15
LI	SOUNUS	P37NIGHT	5
UI	SOUNUS	P37CULS	13
LI	SOUNUS	P37CULS	5

ENDATA

APPENDIX F

APPENDIX F

COMPUTER SOLUTION

The computer print-out in this appendix is the result of running the CDC APEX III package with the input from Appendix E. The print-out includes both a minimum and maximum solution. Specific guidance on interpreting the print-out is found in Chapter III and Appendix E.

NUMBER	NAME	TYPE	STATUS	ROW ACTIVITY	SLACK	DIS. LOA. 4	ROS UPPER	MARGINAL
51	C190240	LE	SLACK	.	.	-INF	.	.
52	C023540	LF	.. BINDING	.	.	-INF	.	.
53	C351740	LE	.. BINDING	.	.	-INF	.	.
54	C172040	LE	SLACK	-1.00000	1.00000	-INF	.	.
55	C242440	LE	SLACK	.	.	-INF	.	.
56	C241540	LE	.. BINDING	.	.	-INF	.	.
57	C152340	LE	.. BINDING	.	.	-INF	.	.
58	C252940	LE	.. BINDING	.	.	-INF	.	.
59	C292640	LE	SLACK	.	.	-INF	.	.
60	C260440	LE	SLACK	-2.00000	2.00000	-INF	.	.
61	C041040	LE	SLACK	.	.	-INF	.	.
62	C101240	LE	SLACK	.	.	-INF	.	.
63	C122040	LE	SLACK	.	.	-INF	.	.
64	C243740	LE	SLACK	.	.	-INF	.	.
65	C23095A1	LE	SLACK	-1.00000	1.00000	-INF	.	.
66	C09105A1	LE	SLACK	.	.	-INF	.	.
67	C14115A1	LE	SLACK	-1.00000	1.00000	-INF	.	.
68	C11025A1	LE	.. BINDING	.	.	-INF	.	.
69	C02245A1	LE	SLACK	-2.00000	2.00000	-INF	.	.
70	C29285A1	LE	SLACK	.	.	-INF	.	.
71	C04205A1	LE	.. BINDING	.	.	-INF	.	.
72	C04205A1	LE	.. BINDING	.	.	-INF	.	.
73	C24255A1	LE	.. BINDING	.	.	-INF	.	.
74	C25105A1	LE	.. BINDING	.	.	-INF	.	.
75	C10125A1	LE	.. BINDING	.	.	-INF	.	.
76	C12205A1	LE	.. BINDING	.	.	-INF	.	.
77	C26375A1	LE	SLACK	-1.00000	1.00000	-INF	.	.
78	C13155A1	LE	.. BINDING	.	.	-INF	.	.
79	C05125A1	LE	.. BINDING	.	.	-INF	.	.
80	C12255A1	LE	.. BINDING	.	.	-INF	.	.
81	C24195A1	LE	.. BINDING	.	.	-INF	.	.
82	C36119A1	LE	.. BINDING	.	.	-INF	.	.
83	C1109MAV	LE	SLACK	-4.00000	4.00000	-INF	.	.
84	C0914MAV	LE	.. BINDING	.	.	-INF	.	.
85	C1410MAV	LE	.. BINDING	.	.	-INF	.	.
86	C1429MAV	LE	.. BINDING	.	.	-INF	.	.
87	C2932MAV	LE	SLACK	.	.	-INF	.	.
88	C3214MAV	LE	.. BINDING	.	.	-INF	.	.
89	C2124MAV	LE	SLACK	.	.	-INF	.	.
90	C2420MAV	LE	.. BINDING	.	.	-INF	.	.
91	C2004MAV	LE	SLACK	.	.	-INF	.	.
92	C0415MAV	LE	.. BINDING	.	.	-INF	.	.
93	C1537MAV	LE	SLACK	.	.	-INF	.	.
94	C1720MAV	LE	.. BINDING	.	.	-INF	.	.
95	C2412MAV	LE	.. BINDING	.	.	-INF	.	.
96	C1226MAV	LE	.. BINDING	.	.	-INF	.	.
97	C2417MAV	LE	.. BINDING	-1.00000	1.00000	-INF	.	.
98	C1425MAV	LE	SLACK	-1.00000	1.00000	-INF	.	.
99	C2411MAV	LE	.. BINDING	.	.	-INF	.	.
100	C1110MAV	LE	SLACK	.	.	-INF	.	.

LINE	NAME	TYPE	STATUS	WIP ACTIVITY	SLACK	100% LOAD	100% UP/PM	MARGINAL
101	C0101ACH	LE	WIP/ING	.	.	-100	.	.
102	C101JACH	LE	SLACK	.	.	-100	.	.
103	C1102ACH	LE	SLACK	.	.	-100	.	.
104	C0517ACH	LE	SLACK	.	.	-100	.	.
105	C1117ACH	LE	WIP/ING	.	.	-100	.	.
106	C1120ACH	LE	WIP/ING	.	.	-100	.	.
107	C2000ACH	LE	SLACK	-1.00000	1.00000	-100	.	.
108	C0109ACH	LE	SLACK	.	.	-100	.	.
109	C0922ACH	LE	WIP/ING	.	.	-100	.	.
110	C2112ACH	LE	WIP/ING	.	.	-100	.	.
111	C1213ACH	LE	WIP/ING	.	.	-100	.	.
112	C2229ACH	LE	WIP/ING	.	.	-100	.	.
113	C2104ACH	LE	WIP/ING	.	.	-100	.	.
114	C0415ACH	LE	WIP/ING	.	.	-100	.	.
115	C1102ACH	LE	WIP/ING	.	.	-100	.	.
116	C0230ACH	LE	SLACK	-1.00000	1.00000	-100	.	.
117	C1025ACH	LE	WIP/ING	.	.	-100	.	.
118	C2524ACH	LE	WIP/ING	.	.	-100	.	.
119	C2420ACH	LE	WIP/ING	.	.	-100	.	.
120	C2011ACH	LE	SLACK	.	.	-100	.	.
121	C1120ACH	LE	SLACK	-1.00000	1.00000	-100	.	.
122	C2109ACH	LE	WIP/ING	.	.	-100	.	.
123	C0905ACH	LE	WIP/ING	.	.	-100	.	.
124	C0514ACH	LE	WIP/ING	.	.	-100	.	.
125	C1407ACH	LE	WIP/ING	.	.	-100	.	.
126	C0710ACH	LE	WIP/ING	.	.	-100	.	.
127	C1010ACH	LE	WIP/ING	.	.	-100	.	.
128	C1013ACH	LE	WIP/ING	.	.	-100	.	.
129	C1101ACH	LE	WIP/ING	.	.	-100	.	.
130	C0129ACH	LE	SLACK	.	.	-100	.	.
131	C2111ACH	LE	WIP/ING	.	.	-100	.	.
132	C1113ACH	LE	SLACK	-1.00000	1.00000	-100	.	.
133	C1100ACH	LE	SLACK	.	.	-100	.	.
134	C0616ACH	LE	SLACK	.	.	-100	.	.
135	C1026ACH	LE	WIP/ING	.	.	-100	.	.
136	C2012ACH	LE	WIP/ING	.	.	-100	.	.
137	C3217ACH	LE	WIP/ING	.	.	-100	.	.
138	C1111ACH	LE	WIP/ING	.	.	-100	.	.
139	C1102ACH	LE	WIP/ING	.	.	-100	.	.
140	C0204ACH	LE	WIP/ING	.	.	-100	.	.
141	C0420ACH	LE	WIP/ING	.	.	-100	.	.
142	C2015ACH	LE	WIP/ING	.	.	-100	.	.
143	C1115ACH	LE	WIP/ING	.	.	-100	.	.
144	C1205ACH	LE	SLACK	-1.00000	1.00000	-100	.	.
145	C2025ACH	LE	SLACK	.	.	-100	.	.
146	C2025ACH	LE	SLACK	.	.	-100	.	.
147	C2012ACH	LE	SLACK	.	.	-100	.	.
148	C1210ACH	LE	SLACK	.	.	-100	.	.

NUMBER	NAME	TYPE	STATUS	COR. ACTIVITY	OUT COST	PRD. LIFE Y	USD. UPPER	MARGINAL
51	P05SAI	INT	ACTIVE	6.00000	1.00000	2.00000	10.00000	.
52	P05MAV	INT	UPPER	6.00000	1.00000	2.00000	6.00000	.
53	P05ACH	INT	UPPER	6.00000	1.00000	2.00000	6.00000	.
54	P05SAM	INT	LOWER	2.00000	1.00000	2.00000	5.00000	.
55	P05MTH	INT	UPPER	2.00000	1.00000	2.00000	6.00000	.
56	P05CUM S	INT	LOWER	6.00000	1.00000	6.00000	9.00000	.
57	P05DUM	INT	ACTIVE	7.00000	1.00000	7.00000	12.00000	.
58	P05SAI	INT	UPPER	13.00000	1.00000	8.00000	13.00000	.
59	P05MAV	INT	UPPER	10.00000	1.00000	6.00000	10.00000	.
60	P05ACH	INT	ACTIVE	8.00000	1.00000	5.00000	10.00000	.
61	P05SAM	INT	UPPER	11.00000	1.00000	7.00000	11.00000	.
62	P05MTH	INT	UPPER	11.00000	1.00000	6.00000	11.00000	.
63	P05CUM S	INT	UPPER	12.00000	1.00000	10.00000	12.00000	.
64	P05DUM	INT	UPPER	16.00000	1.00000	14.00000	16.00000	.
65	P05SAI	INT	UPPER	16.00000	1.00000	15.00000	18.00000	.
66	P05MAV	INT	UPPER	12.00000	1.00000	12.00000	12.00000	.
67	P05ACH	INT	UPPER	7.00000	1.00000	6.00000	12.00000	.
68	P05SAM	INT	UPPER	10.00000	1.00000	9.00000	10.00000	.
69	P05MTH	INT	UPPER	15.00000	1.00000	6.00000	15.00000	.
70	P05CUM S	INT	UPPER	8.00000	1.00000	8.00000	11.00000	.
71	P05DUM	INT	UPPER	11.00000	1.00000	13.00000	16.00000	.
72	P05SAI	INT	UPPER	14.00000	1.00000	13.00000	18.00000	.
73	P05MAV	INT	UPPER	12.00000	1.00000	11.00000	12.00000	.
74	P05ACH	INT	UPPER	9.00000	1.00000	9.00000	12.00000	.
75	P05SAM	INT	UPPER	9.00000	1.00000	8.00000	10.00000	.
76	P05MTH	INT	UPPER	15.00000	1.00000	6.00000	15.00000	.
77	P05CUM S	INT	UPPER	12.00000	1.00000	6.00000	13.00000	.
78	P05DUM	INT	UPPER	16.00000	1.00000	15.00000	16.00000	.
79	P05SAI	INT	UPPER	16.00000	1.00000	16.00000	18.00000	.
80	P05MAV	INT	UPPER	10.00000	1.00000	10.00000	12.00000	.
81	P05ACH	INT	UPPER	8.00000	1.00000	8.00000	12.00000	.
82	P05SAM	INT	UPPER	10.00000	1.00000	9.00000	10.00000	.
83	P05MTH	INT	UPPER	11.00000	1.00000	8.00000	15.00000	.
84	P05CUM S	INT	UPPER	13.00000	1.00000	6.00000	13.00000	.
85	P05DUM	INT	UPPER	9.00000	1.00000	9.00000	11.00000	.
86	P05SAI	INT	UPPER	12.00000	1.00000	7.00000	12.00000	.
87	P05MAV	INT	UPPER	6.00000	1.00000	5.00000	9.00000	.
88	P05ACH	INT	UPPER	7.00000	1.00000	2.00000	7.00000	.
89	P05SAM	INT	UPPER	9.00000	1.00000	7.00000	9.00000	.
90	P05MTH	INT	UPPER	10.00000	1.00000	5.00000	10.00000	.
91	P05CUM S	INT	UPPER	22.00000	1.00000	17.00000	22.00000	.
92	P05DUM	INT	UPPER	7.00000	1.00000	7.00000	12.00000	.
93	P05SAI	INT	UPPER	13.00000	1.00000	9.00000	13.00000	.
94	P05MAV	INT	UPPER	8.00000	1.00000	6.00000	10.00000	.
95	P05ACH	INT	UPPER	8.00000	1.00000	7.00000	8.00000	.
96	P05SAM	INT	UPPER	8.00000	1.00000	7.00000	11.00000	.
97	P05MTH	INT	UPPER	11.00000	1.00000	6.00000	11.00000	.
98	P05CUM S	INT	UPPER	20.00000	1.00000	19.00000	25.00000	.
99	P05DUM	INT	UPPER	14.00000	1.00000	14.00000	16.00000	.
100	P05SAI	INT	UPPER	17.00000	1.00000	16.00000	18.00000	.

NUMBER	NAME	TYPE	STATUS	COM. ACTIVITY	UNIT COST	UNIT COST	UNIT COST	UNIT COST
101	P15MAV	INI	LODR	10.00000	1.00000	10.00000	12.00000	.
102	P15ACH	INI	ACTIVE	8.00000	1.00000	8.00000	12.00000	.
103	P15SAR	INI	ACTIVE	9.00000	1.00000	8.00000	10.00000	.
104	P15NIGH	INI	LODR	15.00000	1.00000	6.00000	15.00000	.
105	P15CUM	INI	ACTIVE	11.00000	1.00000	6.00000	13.00000	.
106	P15GMD	INI	ACTIVE	7.00000	1.00000	6.00000	11.00000	.
107	P15SAI	INI	LODR	12.00000	1.00000	7.00000	12.00000	.
108	P15MAV	INI	LODR	9.00000	1.00000	7.00000	9.00000	.
109	P16ACH	INI	LODR	7.00000	1.00000	4.00000	7.00000	.
110	P16SAM	INI	ACTIVE	4.00000	1.00000	6.00000	9.00000	.
111	P16NIGH	INI	LODR	10.00000	1.00000	5.00000	10.00000	.
112	P16CUM	INI	LODR	22.00000	1.00000	17.00000	22.00000	.
113	P17MD	INI	ACTIVE	13.00000	1.00000	10.00000	13.00000	.
114	P17SAI	INI	ACTIVE	6.00000	1.00000	4.00000	7.00000	.
115	P17MAV	INI	LODR	3.00000	1.00000	1.00000	5.00000	.
116	P17ACH	INI	LODR	6.00000	1.00000	6.00000	6.00000	.
117	P17SAM	INI	LODR	1.00000	1.00000	3.00000	6.00000	.
118	P17NIGH	INI	LODR	2.00000	1.00000	2.00000	4.00000	.
119	P17CUM	INI	LODR	12.00000	1.00000	12.00000	18.00000	.
120	P18MD	INI	LODR	12.00000	1.00000	12.00000	12.00000	.
121	P18SAI	INI	LODR	13.00000	1.00000	8.00000	13.00000	.
122	P18MAV	INI	ACTIVE	10.00000	1.00000	7.00000	10.00000	.
123	P18ACH	INI	ACTIVE	7.00000	1.00000	4.00000	8.00000	.
124	P18SAR	INI	ACTIVE	8.00000	1.00000	8.00000	11.00000	.
125	P18NIGH	INI	ACTIVE	4.00000	1.00000	6.00000	11.00000	.
126	P18CUM	INI	LODR	19.00000	1.00000	19.00000	25.00000	.
127	P19MD	INI	LODR	13.00000	1.00000	13.00000	16.00000	.
128	P19SAI	INI	LODR	17.00000	1.00000	17.00000	18.00000	.
129	P19MAV	INI	LODR	11.00000	1.00000	11.00000	12.00000	.
130	P19ACH	INI	ACTIVE	7.00000	1.00000	7.00000	12.00000	.
131	P19SAR	INI	ACTIVE	9.00000	1.00000	8.00000	10.00000	.
132	P19NIGH	INI	ACTIVE	14.00000	1.00000	6.00000	15.00000	.
133	P19CUM	INI	LODR	13.00000	1.00000	8.00000	13.00000	.
134	P20MD	INI	LODR	14.00000	1.00000	14.00000	16.00000	.
135	P20SAI	INI	ACTIVE	16.00000	1.00000	15.00000	18.00000	.
136	P20MAV	INI	LODR	10.00000	1.00000	10.00000	12.00000	.
137	P20ACH	INI	LODR	9.00000	1.00000	9.00000	12.00000	.
138	P20SAR	INI	ACTIVE	9.00000	1.00000	8.00000	10.00000	.
139	P20NIGH	INI	ACTIVE	13.00000	1.00000	6.00000	15.00000	.
140	P20CUM	INI	LODR	11.00000	1.00000	8.00000	13.00000	.
141	P21MD	INI	LODR	10.00000	1.00000	10.00000	11.00000	.
142	P21SAI	INI	ACTIVE	12.00000	1.00000	8.00000	12.00000	.
143	P21MAV	INI	LODR	8.00000	1.00000	8.00000	9.00000	.
144	P21ACH	INI	LODR	6.00000	1.00000	6.00000	7.00000	.
145	P21SAR	INI	LODR	9.00000	1.00000	9.00000	9.00000	.
146	P21NIGH	INI	LODR	5.00000	1.00000	5.00000	10.00000	.
147	P21CUM	INI	LODR	9.00000	1.00000	9.00000	11.00000	.
148	P22MD	INI	LODR	10.00000	1.00000	10.00000	13.00000	.
149	P22SAI	INI	ACTIVE	7.00000	1.00000	4.00000	7.00000	.
150	P22MAV	INI	LODR	3.00000	1.00000	3.00000	5.00000	.

REPORT #	NAME	TYPE	STATUS	MO	ACTIVITY	UNIT COST	UNIT COST 4	UNIT UPPER	MARGINAL
151	P22ACU1	INT	00	LOST H	6.00000	1.00000	6.00000	6.00000	.
152	P22SAR	INT	00	LOST H	1.00000	1.00000	1.00000	6.00000	.
153	P22HIG1	INT	00	UPPER H	6.00000	1.00000	6.00000	4.00000	.
154	P22CUL S	INT	00	LOST H	12.00000	1.00000	12.00000	10.00000	.
155	P22H1	INT	00	LOST H	6.00000	1.00000	6.00000	12.00000	.
156	P22SAR	INT	00	LOST H	12.00000	1.00000	12.00000	13.00000	.
157	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	10.00000	.
158	P22H1	INT	00	LOST H	6.00000	1.00000	6.00000	10.00000	.
159	P22H1	INT	00	LOST H	6.00000	1.00000	6.00000	11.00000	.
160	P22H1	INT	00	LOST H	11.00000	1.00000	11.00000	11.00000	.
161	P22H1	INT	00	LOST H	12.00000	1.00000	12.00000	12.00000	.
162	P22H1	INT	00	LOST H	14.00000	1.00000	14.00000	16.00000	.
163	P22H1	INT	00	LOST H	17.00000	1.00000	17.00000	16.00000	.
164	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	12.00000	.
165	P22H1	INT	00	LOST H	9.00000	1.00000	9.00000	12.00000	.
166	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	10.00000	.
167	P22H1	INT	00	LOST H	11.00000	1.00000	11.00000	13.00000	.
168	P22H1	INT	00	LOST H	13.00000	1.00000	13.00000	11.00000	.
169	P22H1	INT	00	LOST H	14.00000	1.00000	14.00000	16.00000	.
170	P22H1	INT	00	LOST H	16.00000	1.00000	16.00000	18.00000	.
171	P22H1	INT	00	LOST H	12.00000	1.00000	12.00000	12.00000	.
172	P22H1	INT	00	LOST H	9.00000	1.00000	9.00000	12.00000	.
173	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	10.00000	.
174	P22H1	INT	00	LOST H	15.00000	1.00000	15.00000	15.00000	.
175	P22H1	INT	00	LOST H	8.00000	1.00000	8.00000	13.00000	.
176	P22H1	INT	00	LOST H	14.00000	1.00000	14.00000	16.00000	.
177	P22H1	INT	00	LOST H	16.00000	1.00000	16.00000	18.00000	.
178	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	12.00000	.
179	P22H1	INT	00	LOST H	7.00000	1.00000	7.00000	12.00000	.
180	P22H1	INT	00	LOST H	9.00000	1.00000	9.00000	10.00000	.
181	P22H1	INT	00	LOST H	15.00000	1.00000	15.00000	15.00000	.
182	P22H1	INT	00	LOST H	13.00000	1.00000	13.00000	13.00000	.
183	P22H1	INT	00	LOST H	2.00000	1.00000	2.00000	6.00000	.
184	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	10.00000	.
185	P22H1	INT	00	LOST H	6.00000	1.00000	6.00000	6.00000	.
186	P22H1	INT	00	LOST H	2.00000	1.00000	2.00000	6.00000	.
187	P22H1	INT	00	LOST H	2.00000	1.00000	2.00000	5.00000	.
188	P22H1	INT	00	LOST H	2.00000	1.00000	2.00000	8.00000	.
189	P22H1	INT	00	LOST H	6.00000	1.00000	6.00000	9.00000	.
190	P22H1	INT	00	LOST H	16.00000	1.00000	16.00000	16.00000	.
191	P22H1	INT	00	LOST H	16.00000	1.00000	16.00000	18.00000	.
192	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	12.00000	.
193	P22H1	INT	00	LOST H	12.00000	1.00000	12.00000	12.00000	.
194	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	10.00000	.
195	P22H1	INT	00	LOST H	12.00000	1.00000	12.00000	15.00000	.
196	P22H1	INT	00	LOST H	8.00000	1.00000	8.00000	11.00000	.
197	P22H1	INT	00	LOST H	14.00000	1.00000	14.00000	16.00000	.
198	P22H1	INT	00	LOST H	16.00000	1.00000	16.00000	18.00000	.
199	P22H1	INT	00	LOST H	10.00000	1.00000	10.00000	12.00000	.
200	P22H1	INT	00	LOST H	8.00000	1.00000	8.00000	12.00000	.

NUMBER	NAME	FOOT	STATUS	COR. ACTIVITY	CHS (CUT)	IND LUG 4	WSD DEPTH	MAXIMUM
201	P23SAM	INT	ACTIVE	8.00000	1.00000	7.00000	10.00000	.
202	P23MIGI	INT	UPPER	15.00000	1.00000	6.00000	15.00000	.
203	P23CURS	INT	UPPER	11.00000	1.00000	8.00000	11.00000	.
204	P10MIGI	INT	UPPER	15.00000	1.00000	9.00000	15.00000	.
205	P10SAM	INT	ACTIVE	8.00000	1.00000	7.00000	10.00000	.
206	P10MIGI	INT	UPPER	6.00000	1.00000	4.00000	6.00000	.
207	P10MIGI	INT	UPPER	6.00000	1.00000	3.00000	6.00000	.
208	P10SAM	INT	UPPER	6.00000	1.00000	1.00000	6.00000	.
209	P10MIGI	INT	UPPER	1.00000	1.00000	2.00000	3.00000	.
210	P10MIGI	INT	UPPER	16.00000	1.00000	10.00000	16.00000	.
211	P10MIGI	INT	UPPER	8.00000	1.00000	6.00000	12.00000	.
212	P10SAM	INT	UPPER	13.00000	1.00000	9.00000	13.00000	.
213	P10MIGI	INT	UPPER	10.00000	1.00000	9.00000	10.00000	.
214	P10MIGI	INT	UPPER	8.00000	1.00000	6.00000	8.00000	.
215	P10SAM	INT	UPPER	8.00000	1.00000	8.00000	11.00000	.
216	P10MIGI	INT	UPPER	11.00000	1.00000	6.00000	11.00000	.
217	P10MIGI	INT	UPPER	19.00000	1.00000	19.00000	25.00000	.
218	P10MIGI	INT	UPPER	13.00000	1.00000	13.00000	16.00000	.
219	P10MIGI	INT	UPPER	17.00000	1.00000	17.00000	18.00000	.
220	P10MIGI	INT	UPPER	10.00000	1.00000	9.00000	12.00000	.
221	P10MIGI	INT	UPPER	8.00000	1.00000	8.00000	12.00000	.
222	P10MIGI	INT	UPPER	9.00000	1.00000	9.00000	10.00000	.
223	P10MIGI	INT	UPPER	15.00000	1.00000	6.00000	15.00000	.
224	P10MIGI	INT	UPPER	12.00000	1.00000	8.00000	13.00000	.
225	P10MIGI	INT	UPPER	9.00000	1.00000	9.00000	12.00000	.
226	P10MIGI	INT	UPPER	9.00000	1.00000	9.00000	13.00000	.
227	P10MIGI	INT	UPPER	10.00000	1.00000	8.00000	10.00000	.
228	P10MIGI	INT	UPPER	8.00000	1.00000	6.00000	8.00000	.
229	P10MIGI	INT	UPPER	8.00000	1.00000	8.00000	11.00000	.
230	P10MIGI	INT	UPPER	11.00000	1.00000	6.00000	11.00000	.
231	P10MIGI	INT	UPPER	22.00000	1.00000	19.00000	25.00000	.
232	P10MIGI	INT	UPPER	13.00000	1.00000	10.00000	13.00000	.
233	P10MIGI	INT	UPPER	9.00000	1.00000	4.00000	7.00000	.
234	P10MIGI	INT	UPPER	5.00000	1.00000	3.00000	5.00000	.
235	P10MIGI	INT	UPPER	6.00000	1.00000	6.00000	6.00000	.
236	P10MIGI	INT	UPPER	3.00000	1.00000	3.00000	6.00000	.
237	P10MIGI	INT	UPPER	2.00000	1.00000	2.00000	4.00000	.
238	P10MIGI	INT	UPPER	12.00000	1.00000	12.00000	18.00000	.
239	P10MIGI	INT	UPPER	13.00000	1.00000	10.00000	16.00000	.
240	P10MIGI	INT	UPPER	7.00000	1.00000	9.00000	12.00000	.
241	P10MIGI	INT	UPPER	5.00000	1.00000	5.00000	7.00000	.
242	P10MIGI	INT	UPPER	4.00000	1.00000	4.00000	7.00000	.
243	P10MIGI	INT	UPPER	3.00000	1.00000	3.00000	6.00000	.
244	P10MIGI	INT	UPPER	1.00000	1.00000	2.00000	3.00000	.
245	P10MIGI	INT	UPPER	13.00000	1.00000	13.00000	13.00000	.
246	P10MIGI	INT	UPPER	12.00000	1.00000	10.00000	12.00000	.
247	P10MIGI	INT	UPPER	13.00000	1.00000	10.00000	13.00000	.
248	P10MIGI	INT	UPPER	6.00000	1.00000	6.00000	10.00000	.
249	P10MIGI	INT	UPPER	9.00000	1.00000	6.00000	10.00000	.
250	P10MIGI	INT	UPPER	9.00000	1.00000	9.00000	11.00000	.

INVENTORY	DATE	TYPE	STATUS	COM. ACTIVITY	SLACK	WBS. LOST	WBS. SUPPLY	MARGINAL
1 100		11	HI-00100	602.00000	.	-100	602.00000	-1.00000
2 101		11	SI-ACK	522.00000	29.00000	-100	522.00000	.
3 102		11	SI-ACK	100.00000	4.00000	-100	100.00000	.
4 103		11	SI-ACK	119.00000	43.00000	-100	357.00000	.
5 104		11	HI-00100	113.00000	.	-100	313.00000	-1.00000
6 105		11	SI-ACK	611.00000	.	-100	411.00000	.
7 106		11	HI-00100	522.00000	.	-100	522.00000	-1.00000
8 107		11	SI-ACK	202.00000	-202.00000	-100	100	.
9 108		11	HI-00100	19.00000	.	-100	19.00000	.
10 109		11	SI-ACK	91.00000	6.00000	84.00000	97.00000	.
11 110		11	SI-ACK	80.00000	1.00000	77.00000	89.00000	.
12 111		11	SI-ACK	94.00000	3.00000	84.00000	97.00000	.
13 112		11	SI-ACK	75.00000	1.00000	69.00000	76.00000	.
14 113		11	SI-ACK	89.00000	.	77.00000	89.00000	.
15 114		11	SI-ACK	82.00000	7.00000	77.00000	89.00000	.
16 115		11	HI-00100	19.00000	.	30.00000	39.00000	.
17 116		11	SI-ACK	75.00000	1.00000	69.00000	76.00000	.
18 117		11	SI-ACK	91.00000	6.00000	84.00000	97.00000	.
19 118		11	SI-ACK	93.00000	4.00000	84.00000	97.00000	.
20 119		11	SI-ACK	94.00000	1.00000	84.00000	97.00000	.
21 120		11	SI-ACK	80.00000	1.00000	75.00000	81.00000	.
22 121		11	SI-ACK	81.00000	4.00000	77.00000	89.00000	.
23 122		11	SI-ACK	93.00000	4.00000	84.00000	97.00000	.
24 123		11	HI-00100	75.00000	6.00000	75.00000	81.00000	.
25 124		11	SI-ACK	91.00000	4.00000	84.00000	97.00000	.
26 125		11	SI-ACK	81.00000	4.00000	77.00000	89.00000	.
27 126		11	SI-ACK	89.00000	8.00000	84.00000	97.00000	.
28 127		11	SI-ACK	96.00000	1.00000	84.00000	97.00000	.
29 128		11	HI-00100	65.00000	.	59.00000	65.00000	-1.00000
30 129		11	SI-ACK	56.00000	1.00000	45.00000	51.00000	.
31 130		11	SI-ACK	76.00000	.	69.00000	76.00000	.
32 131		11	SI-ACK	96.00000	1.00000	84.00000	97.00000	.
33 132		11	SI-ACK	96.00000	1.00000	84.00000	97.00000	.
34 133		11	SI-ACK	92.00000	5.00000	84.00000	97.00000	.
35 134		11	HI-00100	11.00000	.	10.00000	19.00000	.
36 135		11	SI-ACK	96.00000	1.00000	84.00000	97.00000	.
37 136		11	SI-ACK	91.00000	6.00000	84.00000	97.00000	.
38 137		11	SI-ACK	62.00000	.	60.00000	62.00000	.
39 138		11	SI-ACK	92.00000	7.00000	77.00000	89.00000	.
40 139		11	SI-ACK	94.00000	1.00000	84.00000	97.00000	.
41 140		11	SI-ACK	80.00000	1.00000	77.00000	89.00000	.
42 141		11	SI-ACK	53.00000	4.00000	45.00000	51.00000	.
43 142		11	SI-ACK	61.00000	5.00000	50.00000	66.00000	.
44 143		11	SI-ACK	75.00000	1.00000	69.00000	76.00000	.
45 144		11	SI-ACK	92.00000	5.00000	84.00000	97.00000	.
46 145		11	HI-00100	.	.	-100	.	.
47 146		11	SI-ACK	-1.00000	1.00000	-100	.	.
48 147		11	SI-ACK	-1.00000	1.00000	-100	.	.
49 148		11	HI-00100	.	.	-100	.	.
50 149		11	HI-00100	.	.	-100	.	.

NUMBER	NAME	TYPE	STATUS	MOD ACTIVITY	SLACK	MODS LOWER	MODS UPPER	MODS FINAL
101	C101ACU1	11	HOLDING	.	.	-100	.	-1.00000
102	C101ACU1	11	HOLDING	.	.	-100	.	-2.00000
103	C1105ACU1	11	SLACK	-1.00000	1.00000	-100	.	.
104	C0537ACU1	11	HOLDING	.	.	-100	.	-1.00000
105	C1119ACU1	11	HOLDING	.	.	-100	.	-2.00000
106	C1420ACU1	11	HOLDING	.	.	-100	.	-3.00000
107	C2600ACU1	11	HOLDING	.	.	-100	.	-4.00000
108	C0509ACU1	11	SLACK	-2.00000	2.00000	-100	.	.
109	C0123ACU1	11	SLACK	.	.	-100	.	.
110	C2312ACU1	11	SLACK	.	.	-100	.	-1.00000
111	C1232ACU1	11	HOLDING	.	.	-100	.	-2.00000
112	C1229ACU1	11	HOLDING	.	.	-100	.	-3.00000
113	C2904ACU1	11	HOLDING	.	.	-100	.	-4.00000
114	C0515ACU1	11	HOLDING	.	.	-100	.	-5.00000
115	C1502ACU1	11	HOLDING	.	.	-100	.	-6.00000
116	C0210ACU1	11	HOLDING	.	.	-100	.	.
117	C1025ACU1	11	SLACK	-2.00000	2.00000	-100	.	.
118	C2524ACU1	11	SLACK	.	.	-100	.	-100
119	C2420ACU1	11	SLACK	.	.	-100	.	-100
120	C2011ACU1	11	SLACK	.	.	-100	.	-100
121	C1120ACU1	11	SLACK	.	.	-100	.	-100
122	C21095AM	11	HOLDING	.	.	-100	.	-100
123	C07075AM	11	HOLDING	.	.	-100	.	-100
124	C05145AM	11	HOLDING	.	.	-100	.	-100
125	C14075AM	11	HOLDING	.	.	-100	.	-100
126	C07105AM	11	HOLDING	.	.	-100	.	-100
127	C10165AM	11	HOLDING	.	.	-100	.	-100
128	C16115AM	11	HOLDING	.	.	-100	.	-100
129	C11015AM	11	HOLDING	.	.	-100	.	-100
130	C01255AM	11	HOLDING	.	.	-100	.	-100
131	C17115AM	11	HOLDING	.	.	-100	.	-100
132	C11115AM	11	HOLDING	.	.	-100	.	-100
133	C10055AM	11	SLACK	-1.00000	1.00000	-100	.	-100
134	C00105AM	11	HOLDING	.	.	-100	.	-100
135	C10205AM	11	HOLDING	.	.	-100	.	-100
136	C26125AM	11	SLACK	.	.	-100	.	-100
137	C12375AM	11	SLACK	.	.	-100	.	-100
138	C37115AM	11	SLACK	.	.	-100	.	-100
139	C11075AM	11	SLACK	.	.	-100	.	-100
140	C02045AM	11	SLACK	.	.	-100	.	-100
141	C04205AM	11	SLACK	.	.	-100	.	-100
142	C20155AM	11	SLACK	.	.	-100	.	-100
143	C15175AM	11	SLACK	.	.	-100	.	-100
144	C14205AM	11	SLACK	.	.	-100	.	-100
145	C23255AM	11	SLACK	.	.	-100	.	-100
146	C25245AM	11	SLACK	.	.	-100	.	-100
147	C24125AM	11	SLACK	.	.	-100	.	-100
148	C12105AM	11	SLACK	.	.	-100	.	-100

[illegible]

NUMBER	NAME	TYPE	STATUS	CUR. ACTIVITY	USD. CUR.	USD. LOCAL	USD. UNPEM	MARGINAL
51	PUNSAI	INT	UNPEM	10.0000	1.0000	2.0000	10.0000	1.0000
52	PUMAV	INT	UNPEM	6.0000	1.0000	2.0000	6.0000	1.0000
53	PUMALH	INT	UNPEM	6.0000	1.0000	2.0000	6.0000	1.0000
54	PUNSAH	INT	LOC	6.0000	1.0000	2.0000	5.0000	1.0000
55	PUMALH	INT	UNPEM	6.0000	1.0000	2.0000	6.0000	1.0000
56	PUMALH	INT	UNPEM	6.0000	1.0000	2.0000	9.0000	1.0000
57	PUMALH	INT	UNPEM	12.0000	1.0000	7.0000	12.0000	1.0000
58	PUMALH	INT	UNPEM	11.0000	1.0000	8.0000	11.0000	1.0000
59	PUMAV	INT	UNPEM	10.0000	1.0000	6.0000	10.0000	1.0000
60	PUMALH	INT	UNPEM	10.0000	1.0000	5.0000	10.0000	1.0000
61	PUMALH	INT	ACTIVE	9.0000	1.0000	7.0000	11.0000	1.0000
62	PUMALH	INT	UNPEM	11.0000	1.0000	6.0000	11.0000	1.0000
63	PUMALH	INT	UNPEM	10.0000	1.0000	10.0000	12.0000	1.0000
64	PUMALH	INT	UNPEM	16.0000	1.0000	14.0000	16.0000	1.0000
65	PUMALH	INT	UNPEM	18.0000	1.0000	15.0000	18.0000	1.0000
66	PUMAV	INT	LOC	12.0000	1.0000	12.0000	12.0000	1.0000
67	PUMALH	INT	ACTIVE	7.0000	1.0000	6.0000	12.0000	1.0000
68	PUMALH	INT	UNPEM	10.0000	1.0000	6.0000	10.0000	1.0000
69	PUMALH	INT	UNPEM	15.0000	1.0000	6.0000	15.0000	1.0000
70	PUMALH	INT	UNPEM	13.0000	1.0000	8.0000	13.0000	1.0000
71	PUMALH	INT	ACTIVE	13.0000	1.0000	13.0000	16.0000	1.0000
72	PUMALH	INT	UNPEM	18.0000	1.0000	13.0000	18.0000	1.0000
73	PUMAV	INT	UNPEM	12.0000	1.0000	11.0000	12.0000	1.0000
74	PUMALH	INT	UNPEM	12.0000	1.0000	9.0000	12.0000	1.0000
75	PUMALH	INT	UNPEM	10.0000	1.0000	8.0000	10.0000	1.0000
76	PUMALH	INT	UNPEM	17.0000	1.0000	6.0000	15.0000	1.0000
77	PUMALH	INT	UNPEM	13.0000	1.0000	8.0000	13.0000	1.0000
78	PUMALH	INT	UNPEM	16.0000	1.0000	15.0000	16.0000	1.0000
79	PUMALH	INT	UNPEM	10.0000	1.0000	16.0000	18.0000	1.0000
80	PUMALH	INT	UNPEM	12.0000	1.0000	10.0000	12.0000	1.0000
81	PUMALH	INT	ACTIVE	10.0000	1.0000	8.0000	12.0000	1.0000
82	PUMALH	INT	UNPEM	10.0000	1.0000	9.0000	10.0000	1.0000
83	PUMALH	INT	UNPEM	15.0000	1.0000	6.0000	15.0000	1.0000
84	PUMALH	INT	UNPEM	13.0000	1.0000	8.0000	13.0000	1.0000
85	PUMALH	INT	UNPEM	11.0000	1.0000	9.0000	11.0000	1.0000
86	PUMALH	INT	UNPEM	12.0000	1.0000	7.0000	12.0000	1.0000
87	PUMALH	INT	UNPEM	9.0000	1.0000	5.0000	9.0000	2.0000
88	PUMALH	INT	UNPEM	7.0000	1.0000	2.0000	7.0000	3.0000
89	PUMALH	INT	UNPEM	9.0000	1.0000	7.0000	9.0000	1.0000
90	PUMALH	INT	UNPEM	10.0000	1.0000	5.0000	10.0000	1.0000
91	PUMALH	INT	UNPEM	22.0000	1.0000	17.0000	22.0000	1.0000
92	PUMALH	INT	ACTIVE	11.0000	1.0000	7.0000	12.0000	1.0000
93	PUMALH	INT	UNPEM	13.0000	1.0000	9.0000	13.0000	1.0000
94	PUMALH	INT	UNPEM	10.0000	1.0000	6.0000	10.0000	1.0000
95	PUMALH	INT	UNPEM	8.0000	1.0000	7.0000	8.0000	1.0000
96	PUMALH	INT	ACTIVE	9.0000	1.0000	7.0000	11.0000	1.0000
97	PUMALH	INT	UNPEM	11.0000	1.0000	6.0000	11.0000	1.0000
98	PUMALH	INT	UNPEM	12.0000	1.0000	19.0000	25.0000	1.0000
99	PUMALH	INT	UNPEM	16.0000	1.0000	14.0000	16.0000	1.0000
100	PUMALH	INT	UNPEM	18.0000	1.0000	16.0000	18.0000	1.0000

Tapout #	Name	Type	Status	Core Activity	MDL Unit	MDL Load	MDL Uptime	MDL INAL
101	P15MAV	INT	UPPER	15.00000	1.00000	10.00000	12.00000	1.00000
102	P15ACHT	INT	ACTIVE	10.00000	1.00000	8.00000	12.00000	.
103	P15SAV	INT	UPPER	10.00000	1.00000	8.00000	10.00000	.
104	P15NIGHT	INT	UPPER	15.00000	1.00000	6.00000	15.00000	1.00000
105	P15CULS	INT	ACTIVE	17.00000	1.00000	8.00000	13.00000	.
106	P15MD	INT	UPPER	11.00000	1.00000	6.00000	11.00000	.
107	P15SAI	INT	UPPER	12.00000	1.00000	7.00000	12.00000	1.00000
108	P15MAV	INT	UPPER	9.00000	1.00000	7.00000	9.00000	1.00000
109	P15ACHT	INT	UPPER	7.00000	1.00000	4.00000	7.00000	1.00000
110	P15SAV	INT	ACTIVE	9.00000	1.00000	6.00000	9.00000	.
111	P15NIGHT	INT	UPPER	10.00000	1.00000	5.00000	10.00000	1.00000
112	P15CULS	INT	ACTIVE	17.00000	1.00000	17.00000	22.00000	.
113	P15MD	INT	UPPER	13.00000	1.00000	10.00000	13.00000	.
114	P15SAI	INT	UPPER	7.00000	1.00000	4.00000	7.00000	1.00000
115	P15MAV	INT	UPPER	5.00000	1.00000	3.00000	5.00000	1.00000
116	P15ACHT	WEA	UPPER	6.00000	1.00000	6.00000	6.00000	1.00000
117	P15SAV	INT	UPPER	6.00000	1.00000	3.00000	6.00000	.
118	P15NIGHT	INT	UPPER	4.00000	1.00000	2.00000	4.00000	1.00000
119	P15CULS	INT	UPPER	12.00000	1.00000	12.00000	14.00000	.
120	P15MD	INT	UPPER	12.00000	1.00000	10.00000	12.00000	.
121	P15SAI	INT	UPPER	13.00000	1.00000	8.00000	13.00000	1.00000
122	P15MAV	INT	UPPER	10.00000	1.00000	7.00000	10.00000	1.00000
123	P15ACHT	INT	ACTIVE	7.00000	1.00000	4.00000	8.00000	.
124	P15SAV	INT	UPPER	9.00000	1.00000	8.00000	11.00000	.
125	P15NIGHT	INT	UPPER	11.00000	1.00000	6.00000	11.00000	1.00000
126	P15CULS	INT	UPPER	19.00000	1.00000	19.00000	25.00000	.
127	P15MD	INT	ACTIVE	13.00000	1.00000	13.00000	16.00000	.
128	P15SAI	INT	UPPER	14.00000	1.00000	17.00000	14.00000	1.00000
129	P15MAV	INT	UPPER	12.00000	1.00000	11.00000	12.00000	1.00000
130	P15ACHT	INT	ACTIVE	8.00000	1.00000	7.00000	12.00000	.
131	P15SAV	INT	UPPER	10.00000	1.00000	8.00000	10.00000	1.00000
132	P15NIGHT	INT	UPPER	15.00000	1.00000	6.00000	15.00000	.
133	P15CULS	INT	UPPER	13.00000	1.00000	8.00000	13.00000	1.00000
134	P15MD	INT	UPPER	16.00000	1.00000	14.00000	16.00000	.
135	P15SAI	INT	UPPER	18.00000	1.00000	15.00000	14.00000	1.00000
136	P15MAV	INT	UPPER	12.00000	1.00000	10.00000	12.00000	1.00000
137	P15ACHT	INT	UPPER	12.00000	1.00000	9.00000	12.00000	1.00000
138	P15SAV	INT	UPPER	10.00000	1.00000	8.00000	10.00000	.
139	P15NIGHT	INT	UPPER	15.00000	1.00000	6.00000	15.00000	1.00000
140	P15CULS	INT	UPPER	13.00000	1.00000	8.00000	13.00000	.
141	P15MD	INT	UPPER	16.00000	1.00000	10.00000	11.00000	-1.00000
142	P15SAI	INT	UPPER	12.00000	1.00000	8.00000	12.00000	.
143	P15MAV	INT	UPPER	9.00000	1.00000	8.00000	9.00000	.
144	P15ACHT	INT	UPPER	7.00000	1.00000	6.00000	7.00000	-1.00000
145	P15SAV	WEA	UPPER	9.00000	1.00000	9.00000	9.00000	.
146	P15NIGHT	INT	UPPER	9.00000	1.00000	5.00000	10.00000	-1.00000
147	P15CULS	INT	UPPER	9.00000	1.00000	9.00000	11.00000	.
148	P15MD	INT	UPPER	10.00000	1.00000	10.00000	13.00000	1.00000
149	P15SAI	INT	UPPER	7.00000	1.00000	4.00000	7.00000	1.00000
150	P15MAV	INT	UPPER	5.00000	1.00000	3.00000	5.00000	1.00000

NUMBER	NAME	TYPE	STATUS	CUR	ACTIVITY	OFF	CURR	USD	INP/CM	MAINTENAL
151	PZACHT	INT	ACTIVE	1.0000	6.0000	1.0000	6.0000	6.0000	6.0000	1.0000
152	PZASAT	INT	ACTIVE	1.0000	6.0000	1.0000	3.0000	4.0000	6.0000	1.0000
153	PZCHLUS	INT	ACTIVE	1.0000	14.0000	1.0000	12.0000	18.0000	18.0000	1.0000
154	PZCHLUS	INT	ACTIVE	1.0000	11.0000	1.0000	8.0000	12.0000	12.0000	1.0000
155	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	8.0000	13.0000	13.0000	1.0000
156	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	7.0000	10.0000	10.0000	1.0000
157	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	5.0000	10.0000	10.0000	1.0000
158	PZCHLUS	INT	ACTIVE	1.0000	9.0000	1.0000	7.0000	11.0000	11.0000	1.0000
159	PZCHLUS	INT	ACTIVE	1.0000	11.0000	1.0000	6.0000	11.0000	11.0000	1.0000
160	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	10.0000	12.0000	12.0000	1.0000
161	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	14.0000	16.0000	16.0000	1.0000
162	PZCHLUS	INT	ACTIVE	1.0000	18.0000	1.0000	17.0000	18.0000	18.0000	1.0000
163	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	9.0000	12.0000	12.0000	1.0000
164	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	8.0000	12.0000	12.0000	1.0000
165	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	9.0000	10.0000	10.0000	1.0000
166	PZCHLUS	INT	ACTIVE	1.0000	15.0000	1.0000	13.0000	15.0000	15.0000	1.0000
167	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	14.0000	16.0000	16.0000	1.0000
168	PZCHLUS	INT	ACTIVE	1.0000	18.0000	1.0000	15.0000	18.0000	18.0000	1.0000
169	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	11.0000	12.0000	12.0000	1.0000
170	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	8.0000	10.0000	10.0000	1.0000
171	PZCHLUS	INT	ACTIVE	1.0000	15.0000	1.0000	6.0000	15.0000	15.0000	1.0000
172	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	14.0000	16.0000	16.0000	1.0000
173	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	10.0000	16.0000	16.0000	1.0000
174	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	8.0000	12.0000	12.0000	1.0000
175	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	6.0000	13.0000	13.0000	1.0000
176	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	14.0000	16.0000	16.0000	1.0000
177	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	10.0000	12.0000	12.0000	1.0000
178	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	7.0000	10.0000	10.0000	1.0000
179	PZCHLUS	INT	ACTIVE	1.0000	15.0000	1.0000	6.0000	15.0000	15.0000	1.0000
180	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	14.0000	16.0000	16.0000	1.0000
181	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	10.0000	16.0000	16.0000	1.0000
182	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	8.0000	12.0000	12.0000	1.0000
183	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	6.0000	13.0000	13.0000	1.0000
184	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	14.0000	16.0000	16.0000	1.0000
185	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	10.0000	12.0000	12.0000	1.0000
186	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	7.0000	10.0000	10.0000	1.0000
187	PZCHLUS	INT	ACTIVE	1.0000	15.0000	1.0000	6.0000	15.0000	15.0000	1.0000
188	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	14.0000	16.0000	16.0000	1.0000
189	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	10.0000	16.0000	16.0000	1.0000
190	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	8.0000	12.0000	12.0000	1.0000
191	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	6.0000	13.0000	13.0000	1.0000
192	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	14.0000	16.0000	16.0000	1.0000
193	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	10.0000	12.0000	12.0000	1.0000
194	PZCHLUS	INT	ACTIVE	1.0000	10.0000	1.0000	7.0000	10.0000	10.0000	1.0000
195	PZCHLUS	INT	ACTIVE	1.0000	15.0000	1.0000	6.0000	15.0000	15.0000	1.0000
196	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	14.0000	16.0000	16.0000	1.0000
197	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	10.0000	16.0000	16.0000	1.0000
198	PZCHLUS	INT	ACTIVE	1.0000	12.0000	1.0000	8.0000	12.0000	12.0000	1.0000
199	PZCHLUS	INT	ACTIVE	1.0000	13.0000	1.0000	6.0000	13.0000	13.0000	1.0000
200	PZCHLUS	INT	ACTIVE	1.0000	16.0000	1.0000	14.0000	16.0000	16.0000	1.0000

NUMBER	NAME	TYPE	STATUS	ACTIVITY	4303 CTR	ONE LOG	DRD UPPER	MAGNITUDE
251	PLANETARY	INT	UPPER	000000.1	000000.1	000000.8	000000.1	1.00000
252	PLANETARY	INT	UPPER	000000.5	000000.1	000000.9	000000.1	1.00000
253	PLANETARY	INT	UPPER	000000.0	000000.1	000000.4	000000.0	1.00000
254	PLANETARY	INT	UPPER	000000.0	000000.1	000000.7	000000.2	1.00000
255	PLANETARY	INT	UPPER	000000.2	000000.1	000000.9	000000.1	1.00000
256	PLANETARY	INT	UPPER	000000.4	000000.1	000000.9	000000.1	1.00000
257	PLANETARY	INT	UPPER	000000.9	000000.1	000000.0	000000.1	1.00000
258	PLANETARY	INT	UPPER	000000.1	000000.1	000000.0	000000.1	1.00000

APPENDIX G

APPENDIX G

SCHEDULER'S HANDBOOK

This appendix is designed to provide a simple step by step guide for using the scheduling system developed during research into optimizing sortie allocation in an A-7D squadron. This interactive system is designed for the scheduler to use a computer terminal in the squadron which gives access to a central computer facility and the LP program. The actions required can be categorized into three phases: preparation, input, and analysis. These three phases will be explained in chronological order.

The first phase, preparation, involves collecting and formatting required data so that it will be available in the proper sequence for input into the computer. The initial step is to establish the projected planning sorties of each type for the upcoming training cycle. This information must be broken down according to the maximum numbers by WD, SAT, MAV, SAR, NIGHT, and COLS sorties. In addition, for each pilot assigned or attached for flying, the following data must be collected:

- Pilot training category (CT or IQT/MQT)

- Pilot category (Primary or Staff)

- Pilot's current or projected mission status (MR or MS)

- Experience level (Experienced or Inexperienced)

- Pilots designated as IPs

GCC level assigned (A, B, or C)

Additional tasking (Night or SAR)

Pilot ranking for each type sortie

Collection of this data can be simplified by generation of a local form with columns arranged similar to the example in Figure 7. With the data available and formatted for the input process, it will take from twenty to thirty minutes to input the information to the computer.

The input phase is not complicated and does not take any great amount of training to accomplish. The first step is to gain access to the computer system. The procedures required to accomplish this task are normally generated locally and will be provided by the local DPI. Once access to the system is obtained, the scheduler must bring the FORTRAN computer assisted scheduling program into the local working space for execution. When the program is executed, a series of questions appear on the display device. The questions and required responses are illustrated in Figure 8.

In addition to the questions which will appear on the display device, the program contains several error statements which will appear when improper data is input. The computer error messages which may be generated and the required responses are illustrated in Figure 9.

After the data for each of the pilots has been entered the scheduler must input 999 for the last pilot number to direct the program to perform a subroutine to generate the proper format for the input of the output from the FORTRAN computer assisted scheduling program to the LP package for generation of a solution. To generate the solution, the output from the FORTRAN computer assisted scheduling program must be input into the LP package used by the system. This is

Question	Response
1. Total number of pilots?	Enter the number of pilots who will be scheduled for flying during the training cycle.
2. Maximum number of WD, SAT, MAV, ACBT, SAR, Night, COLS sorties?	Enter in order the maximum number of each type sortie forecast to be available for the training cycle.
3. Pilot number?	Each pilot is numbered consecutively from 1 to the maximum entered for the question in number 1. Enter 999 when all the pilots have been entered.
4. Training category--CT=1, IQT/MQT=2?	If a pilot is entered or already in CT enter 1. If a pilot is going through IQT/MQT enter 2.
5. Months to complete IQT/MQT--1,2,3,4?	Enter the number of months the pilot is expected to take to complete training in months from 1 to 4.
6. Pilot category--Primary=1, Staff=2?	Enter a 1 if the pilot is a primary unit pilot and a 2 if the pilot is a staff pilot.
7. Status after IQT/MQT--MR=1, MS=2?	If the pilot will enter CT and become MR after completion of training enter 1. If the pilot will not become MR then enter 2.
8. Pilot status--MR=1, MS=2?	Enter a 1 for an MR pilot and 2 for a non MR pilot.
9. Experience=1, Inexperience=2?	If a pilot is classified as experienced enter a 1 otherwise enter a 2.

Figure 8

Question/Response

Question	Response
10. Is pilot an IP--Yes=1, No=2?	If pilot serves as an IP or SEFE enter a 1, if not enter a 2.
11. GCC level--A=1, B=2, C=3?	Enter the appropriate number for the assigned GCC level: A=1, B=2, C=3.
12. Ranking for WD, SAT, MAV, ACBT, SAR sorties?	Enter in order the ranking for each type sortie for each pilot.

Figure 8 (Continued)

Statement	Response
1. Illegal entry try again	Check and reenter required data. This will normally occur when an entry is not one of the inputs allowed. For example, inputting a 3 when only a 1 or 2 entry is allowed.
2. Max pilots allowed is 50 must change program	This will be printed if the number entered for the total number of pilots in question 1, Figure 9, exceeds 50. If more than 50 pilots are assigned the program will have to be modified to make the arrays and matrices larger to accommodate the additional data.
3. Ranks must be in Range 1 to # pilots = "	This entry is printed when a number is entered greater than the total number of pilots entered in response to question 12, Figure 9.
4. Conflict with pilot " " ranks = "	This entry is printed when two pilots with the same ranking are entered in response to question 12, Figure 9.

Figure 9

Statement/Response

accomplished by following the locally established procedures to run the program. Once the program is run, the output can be routed to a printer or displayed on the local display device depending on local capabilities. Generation of the computer solution completes the input phase and provides the product which is evaluated in the final phase.

The computer solution generated by this process allows the scheduler to evaluate sortie requirements on three different levels. The first level is made up of the gross total figures for each sortie type relative to the input for the planning factors for the training period. The next higher level includes a breakout of total sorties by pilot, but does not break the total sorties down by type. The last level consists of a breakout of sorties by type for each pilot.

Evaluation of the first level involves interpretation of the first eight rows of the CONSTRAINTS section of the computer solution as reproduced in Figure 10. The entries in the RHS UPPER column represents the planning factors input by the scheduler. The entries in the ROW ACTIVITY column are the solutions for the number of sorties required or desired. The entry in the SLACK column shows the difference between the input and the computer solution (ROW ACTIVITY entry). Positive entries in the SLACK column indicate an excess capacity, while negative entries indicate a shortage. The other column of interest is the MARGINAL column. An entry in the MARGINAL column indicates the rate at which the total sorties changes per unit change of the type of sortie. A negative sign indicates an improvement in the total sorties and a positive sign indicates a degradation in the total sorties. By comparing the maximum and minimum solutions the scheduler can arrive

MAXIMIZE							
NUMBER	NAME	TYPE	STATUS	ROW ACTIVITY	SLACK	RHS LOWER	RHS UPPER
1	TWD	LE	SLACK	446.00000	11.00000	-INF	457.00000
2	TSAT	LE	SLACK	517.00000	32.00000	-INF	549.00000
3	TMAV	LE	SLACK	355.00000	4.00000	-INF	359.00000
4	TACBT	LE	SLACK	295.00000	9.00000	-INF	304.00000
5	TSAR	LE	BINDING	285.00000	.	-INF	285.00000
6	TNIGHT	LE	SLACK	331.00000	64.00000	-INF	395.00000
7	TCOLS	LE	SLACK	518.00000	16.00000	-INF	534.00000
8	TOTALS	FR	SLACK	2747.00000	-2747.00000	-INF	+INF
							MARGINAL
							.
							.
							.
							-1.00000
							.
							.
							.

MINIMIZE							
NUMBER	NAME	TYPE	STATUS	ROW ACTIVITY	SLACK	RHS LOWER	RHS UPPER
1	TWD	LE	SLACK	404.00000	53.00000	-INF	457.00000
2	TSAT	LE	SLACK	435.00000	114.00000	-INF	549.00000
3	TMAV	LE	SLACK	297.00000	62.00000	-INF	359.00000
4	TACBT	LE	SLACK	249.00000	55.00000	-INF	304.00000
5	TSAR	LE	SLACK	285.00000	.	-INF	285.00000
6	TNIGHT	LE	SLACK	228.00000	167.00000	-INF	395.00000
7	TCOLS	LE	SLACK	443.00000	91.00000	-INF	534.00000
8	TOTALS	FR	SLACK	2341.00000	-2341.00000	-INF	+INF
							MARGINAL
							.
							.
							.
							.
							.
							.
							.

Figure 10

Level One

at an idea of the range of sorties which could be used efficiently under either limited or plentiful sortie availability.

Using Figure 10 an example can be given to clarify the process of interpretation for this level. The same inputs were used in both the maximum and minimum solutions depicted. From line eight it can be seen that the sorties needed to meet the needs of all the pilots would be 2,341 at a minimum level or 2,747 at the maximum level. When 285 sorties are input as the SAR (line 5) planning factor, the ACTIVITY column shows a solution of 285 sorties with no excess apparent in the SLACK column. The -1 entry in the MARGINAL column for SAR sorties indicates that if an additional SAR sortie could be generated the total number of sorties would improve by one. Evaluating the WD row (line 1) shows there is excess WD sorties available at both maximum (53 excess) and minimum (11 excess) sortie rates. The difference between the two rates, 42 (53-11) sorties, should not be converted to another type of sortie or returned to another unit to satisfy their needs since these sorties can be efficiently used by the unit. Only eleven of the WD sorties should be considered for conversion to another type of sortie or returned for use by another unit. Since the configuration of both SAT (line 2) and MAV (line 3) aircraft are compatible with the SAR mission and there are excess sorties of both types, the excess sorties of either type could be converted to SAR missions and the total number of sorties flown could be efficiently increased by one for each sortie converted to a SAR mission. This same process is applicable for any type sortie where aircraft configurations are compatible.

Level one provided a general view of the total sortie requirements by type. Level two provides a more refined view by allowing the

total allocation for each pilot to be evaluated. To simplify the explanation of the information available in level two, pilot P04 will be used as an example.

From the minimize section of Figure 11 the minimum number of sorties which should be allocated to P04 (line 12) would be seventy three (RHS LOWER). The maximum number should be eighty six (RHS UPPER). The difference between the maximum and minimum sorties is thirteen (SLACK) which could be used should P04 have problems which required extra training. The -1 (MARGINAL) value indicates the total number of sorties for the unit could be improved by one sortie if P04 were to be given one less sortie. However, since P04 is already at a minimum level, he should not be given any fewer sorties unless he is to be regressed to a lower GCC level.

From the maximum section of Figure 11 the maximum number of sorties which P04 should be allocated is again seventy three (ROW ACTIVITY). Since both the maximum and minimum solutions are the same, the scheduler should make every attempt to allocate seventy three sorties to P04. The -4 (MARGINAL) entry means every additional sortie allocated to P04 would result in a change of four in the total sorties for the unit. This is true because if P04 were given one additional sortie the program would also have to allocate additional sorties to other pilots.

When the maximum and minimum solutions (ROW ACTIVITY) for a pilot differ as is the case for P10 (line 18, Figure 11) significant information can be deduced. The difference between the lower and upper rate of flying should be regarded as the minimum number of sorties held in reserve for the pilot. For P10, four sorties would be

MAXIMIZE

NUMBER	NAME	TYPE	STATUS	ROW ACTIVITY	SLACK	RHS LOWER	RHS UPPER	MARGINAL
9	P01	BLE	SLACK	36.00000	3.00000	30.00000	39.00000	.
10	P02	BLE	SLACK	83.00000	3.00000	73.00000	86.00000	.
11	P03	BLE	SLACK	78.00000	3.00000	69.00000	81.00000	.
12	P04	BLE	BINDING	73.00000	13.00000	73.00000	86.00000	-4.00000
13	P05	BLE	SLACK	67.00000	1.00000	56.00000	68.00000	.
14	P06	BLE	SLACK	78.00000	3.00000	69.00000	81.00000	.
15	P07	BLE	SLACK	79.00000	2.00000	69.00000	81.00000	.
16	P08	BLE	SLACK	39.00000	.	30.00000	39.00000	.
17	P09	BLE	SLACK	64.00000	4.00000	56.00000	68.00000	.
18	P10	BLE	SLACK	77.00000	9.00000	73.00000	86.00000	.

MINIMIZE

NUMBER	NAME	TYPE	STATUS	ROW ACTIVITY	SLACK	RHS LOWER	RHS UPPER	MARGINAL
9	P01	BLE	BINDING	30.00000	9.00000	30.00000	39.00000	-1.00000
10	P02	BLE	BINDING	73.00000	13.00000	73.00000	86.00000	-1.00000
11	P03	BLE	BINDING	69.00000	12.00000	69.00000	81.00000	-1.00000
12	P04	BLE	BINDING	73.00000	13.00000	73.00000	86.00000	-1.00000
13	P05	BLE	BINDING	56.00000	12.00000	56.00000	68.00000	-1.00000
14	P06	BLE	BINDING	69.00000	12.00000	69.00000	81.00000	-1.00000
15	P07	BLE	BINDING	69.00000	12.00000	69.00000	81.00000	-1.00000
16	P08	BLE	BINDING	30.00000	9.00000	30.00000	39.00000	-1.00000
17	P09	BLE	BINDING	56.00000	12.00000	56.00000	68.00000	-1.00000
18	P10	BLE	BINDING	73.00000	13.00000	73.00000	86.00000	-1.00000

Figure 11

Level Two

held in reserve and the remaining nine (SLACK) of the maximum solution could be used for another purpose or not used at all.

Level three provides the greatest amount of detail for the scheduler. It allows an evaluation of the various sortie types for each pilot. Pilot P01 will be used to explain the evaluation process for this level using Figure 12.

Both the minimum and maximum solutions for pilot P01 WD, ABCT, SAR, NIGHT, and COLS are equal as indicated in the print-out (lines 1, 4, 5, 6, and 7). This indicates P01 should be allocated the same number of these sorties under most conditions. The solution further shows that P01 should be scheduled for between five and ten SAT sorties even though the acceptable range would be from two (BND LOWER) to ten (BND UPPER). The MAV sortie spread is from two to six which is the same as the acceptable limits (BND LOWER to BND UPPER).

An important factor is identified by the -1 (MARGINAL) entry (line 5). The number of SAR sorties available are a limiting factor which was previously noted in level one. If more SAR sorties were made available, the number of SAR sorties allocated to P01 would increase under the maximum allocation condition. Likewise, the total number of sorties would increase by one sortie for each sortie allocated to P01.

A negative entry in the MARGINAL column is an indication of who should be given more (maximum condition) or fewer (minimum condition) sorties. The larger the number the greater the effect on the total sorties for each sortie either given or taken away. A positive entry in the MARGINAL column is an indication of who should not be given more (maximum condition) or fewer (minimum condition) sorties.

MAXIMUM								
NUMBER	NAME	TYPE	STATUS	COL ACTIVITY	OBJ COEF	BND LOWER	BND UPPER	MARGINAL
1	P01WD	INT	ACTIVE	2.00000	1.00000	2.00000	6.00000	.
2	P01SAT	INT**	UPPER	10.00000	1.00000	2.00000	10.00000	.
3	P01NAV	INT**	UPPER	6.00000	1.00000	2.00000	6.00000	.
4	P01ACBT	INT**	UPPER	6.00000	1.00000	2.00000	6.00000	.
5	P01SAR	INT	LOWER	2.00000	1.00000	2.00000	5.00000	-1.00000
6	P01NIGHT	INT**	UPPER	4.00000	1.00000	2.00000	4.00000	.
7	P01COLS	INT**	UPPER	9.00000	1.00000	6.00000	9.00000	.
8	P02WD	INT	ACTIVE	13.00000	1.00000	13.00000	16.00000	.
9	P02SAT	INT**	UPPER	18.00000	1.00000	14.00000	18.00000	.
10	P02NAV	BFX**	LOWER	12.00000	1.00000	12.00000	12.00000	.
11	P02ACBT	INT**	UPPER	10.00000	1.00000	8.00000	10.00000	.
12	P02SAR	INT	LOWER	10.00000	1.00000	10.00000	12.00000	-1.00000

MINIMUM								
NUMBER	NAME	TYPE	STATUS	COL ACTIVITY	OBJ COEF	BND LOWER	BND UPPER	MARGINAL
1	P01WD	INT*	LOWER	2.00000	1.00000	2.00000	6.00000	.
2	P01SAT	INT	ACTIVE	5.00000	1.00000	2.00000	10.00000	.
3	P01NAV	INT**	LOWER	2.00000	1.00000	2.00000	6.00000	.
4	P01ACBT	INT**	UPPER	6.00000	1.00000	2.00000	6.00000	.
5	P01SAR	INT**	LOWER	2.00000	1.00000	2.00000	5.00000	.
6	P01NIGHT	INT**	UPPER	4.00000	1.00000	2.00000	4.00000	.
7	P01COLS	INT*	UPPER	9.00000	1.00000	6.00000	9.00000	.
8	P02WD	INT**	LOWER	13.00000	1.00000	13.00000	16.00000	.
9	P02SAT	INT	ACTIVE	15.00000	1.00000	14.00000	18.00000	.
10	P02NAV	BFX**	LOWER	12.00000	1.00000	12.00000	12.00000	.
11	P02ACBT	INT**	LOWER	8.00000	1.00000	8.00000	10.00000	.
12	P02SAR	INT**	LOWER	10.00000	1.00000	10.00000	12.00000	.

Figure 12
Level Three

The guidelines provided in this handbook apply to the computer generated print-outs from the Control Data Corporation APEX III program and the Burroughs' TEMPO program. Both of these programs are for solving linear or integer programming models.

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